

FIRE PROTECTION AND DETECTION SYSTEM: HARDENED AIRCRAFT SHELTER (HAS) PERSONNEL EGRESS AND FUEL SECURING

**J.A. CENTRONE, H.D. BEESON, J.K. NEWMAN,
T.J. STEPETIC, B. DEES, K. MOSER, J.L. WALKER**

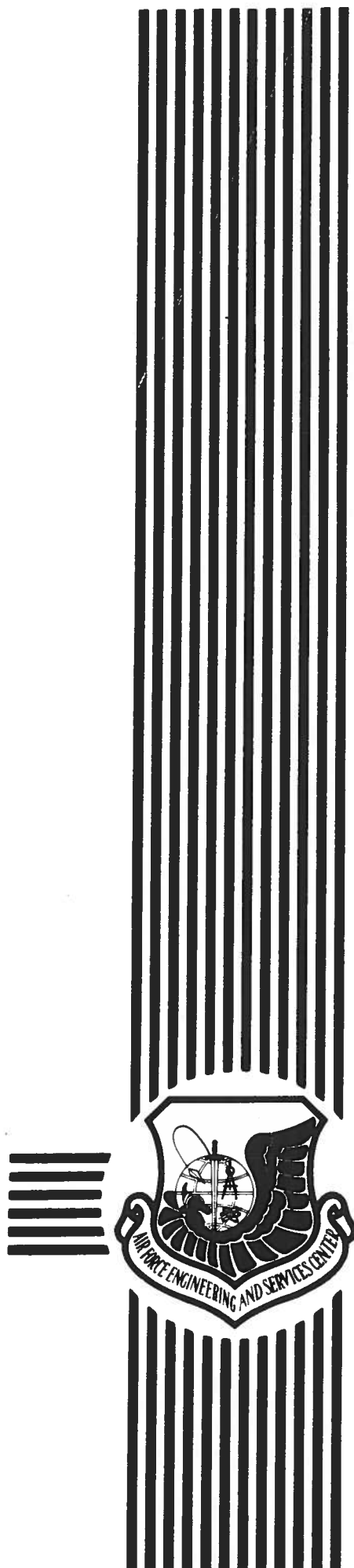
**NEW MEXICO ENGINEERING RESEARCH INSTITUTE
P.O. BOX 25
UNIVERSITY OF NEW MEXICO
ALBUQUERQUE NM 87131**

JULY 1988

FINAL REPORT

JANUARY 1986 - NOVEMBER 1986

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED



**ENGINEERING & SERVICES LABORATORY
AIR FORCE ENGINEERING & SERVICES CENTER
TYNDALL AIR FORCE BASE, FLORIDA 32403**

Unlimited

ESL-TR-87-69

FIRE PROTECTION AND DETECTION SYSTEM: HARDENED AIRCRAFT SHELTER (HAS) PERSONNEL EGRESS AND FUEL SECURING

**J.A. CENTRONE, H.D. BEESON, J.K. NEWMAN,
T.J. STEPETIC, B. DEES, K. MOSER, J.L. WALKER**

**NEW MEXICO ENGINEERING RESEARCH INSTITUTE
P.O. BOX 25
UNIVERSITY OF NEW MEXICO
ALBUQUERQUE NM 87131**

JULY 1988

FINAL REPORT

JANUARY 1986 - NOVEMBER 1986

DISCLAIMER

This document is submitted as an historical record of work performed. Limitations of the available media rendered editing impractical; therefore it is retained "as is."

NOTICE

PLEASE DO NOT REQUEST COPIES OF THIS REPORT FROM
HQ AFESC/RD (ENGINEERING AND SERVICES LABORATORY).
ADDITIONAL COPIES MAY BE PURCHASED FROM:

NATIONAL TECHNICAL INFORMATION SERVICE
5285 PORT ROYAL ROAD
SPRINGFIELD, VIRGINIA 22161

FEDERAL GOVERNMENT AGENCIES AND THEIR CONTRACTORS
REGISTERED WITH DEFENSE TECHNICAL INFORMATION CENTER
SHOULD DIRECT REQUESTS FOR COPIES OF THIS REPORT TO:

DEFENSE TECHNICAL INFORMATION CENTER
CAMERON STATION
ALEXANDRIA, VIRGINIA 22314

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS														
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release. Distribution unlimited.														
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE																	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NMERI WA3-38 (3.06)			5. MONITORING ORGANIZATION REPORT NUMBER(S) ESL-TR-87-69														
6a. NAME OF PERFORMING ORGANIZATION New Mexico Engineering Research Institute		6b. OFFICE SYMBOL (If applicable) NMERI		7a. NAME OF MONITORING ORGANIZATION Engineering and Services Laboratory													
6c. ADDRESS (City, State and ZIP Code) Box 25, University of New Mexico Albuquerque, New Mexico 87131		7b. ADDRESS (City, State and ZIP Code) Air Force Engineering and Services Center Tyndall Air Force Base, Florida 32403															
8a. NAME OF FUNDING/SPONSORING ORGANIZATION HQ AFESC		8b. OFFICE SYMBOL (If applicable) RDCF		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Contract No. F29601-84-C-0080													
8c. ADDRESS (City, State and ZIP Code) Tyndall AFB FL 32403-6001		10. SOURCE OF FUNDING NOS. <table border="1"><tr><td>PROGRAM ELEMENT NO.</td><td>PROJECT NO.</td><td>TASK NO.</td><td>WORK UNIT NO.</td></tr><tr><td>64708F</td><td>2505</td><td></td><td></td></tr></table>				PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.	64708F	2505						
PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.														
64708F	2505																
11. TITLE (Include Security Classification) FIRE PROTECTION AND DETECTION SYSTEM: HARDENED		AIRCRAFT SHELTER (HAS) (Continued)															
12. PERSONAL AUTHOR(S) John A. Centrone, Harold D. Beeson, J. Kent Newman, Thomas J. Stepetic, (Continued)																	
13a. TYPE OF REPORT Final Report		13b. TIME COVERED FROM 1/86 TO 11/86		14. DATE OF REPORT (Yr., Mo., Day) July 1988													
				15. PAGE COUNT 120													
16. SUPPLEMENTARY NOTATION Availability of this report is specified on reverse of front cover.																	
17. COSATI CODES <table border="1"><tr><th>FIELD</th><th>GROUP</th><th>SUB. GR.</th></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr></table>			FIELD	GROUP	SUB. GR.										18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Fuel Securing, Halon 1211, Personnel Egress, AFFF, Stimuli Sampling, Burnback Resistance		
FIELD	GROUP	SUB. GR.															
19. ABSTRACT (Continue on reverse if necessary and identify by block number) <p>A recent Air Force Study resulted in the development of a fire detection and suppression system for tactical hardened aircraft shelters (HAS). This study recommended adjunct efforts be undertaken to assure that personnel within the HAS at the time of activation of the fire suppression system (Halon 1211) are provided the means of safe and rapid egress, and that an ancillary fuel securing system be provided within the HAS to secure fuel spills from ignition. This project provided the market surveys, comparative research, development, and physical testing which shall lead to procurement definition of both a personnel egress and fuel securing system. Many of the market surveys and much of the comparative research was performed via a subcontract to AMETEK, Offshore Research Engineering Division. Four smoke tests and one neat Halon 1211 discharge were used to test a wide variety of egress system combinations. The UL 162 wand and stovepipe tests were used to test the fuel-securing system. All testing was conducted at Tyndall AFB, Florida, and</p>																	
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input checked="" type="checkbox"/> DTIC USERS <input type="checkbox"/>			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED														
22a. NAME OF RESPONSIBLE INDIVIDUAL Joseph L. Walker		22b. TELEPHONE NUMBER (Include Area Code) (904) 283-6194		22c. OFFICE SYMBOL HQ AFESC/RDCF													

11. TITLE (Concluded)

PERSONNEL EGRESS AND FUEL SECURING

12. AUTHORS (Concluded)

Billy Dees, Keith Moser, and Joseph L. Walker

19. ABSTRACT (Concluded)

was considered highly successful in determining system performance. All survey, research and test results are contained in the report. The result of this effort is the final report which contains Military Purchase Descriptions for both the Personnel Egress System and the Fuel Securing System.

PREFACE

This final technical report was prepared by the New Mexico Engineering Research Institute (NMERI), University of New Mexico, Campus Box 25, Albuquerque, New Mexico 87131, under contract F29601-84-C-0080 (Subtask 3.06), for the Air Force Engineering and Services Center, Engineering and Services Laboratory (HQ AFESC/RDCF), Tyndall Air Force Base, Florida 32403-6001.

This report summarizes the work done between 30 July 1986 and 1 July 1987. HQ AFESC/RDCF program manager was Mr Joseph L. Walker.

The authors would like to acknowledge the support and assistance provided by the following individuals: Chief John C. Stokes and his personnel from Tyndall Air Force Base Fire Department; Mr Loren M. Womack and his personnel assigned to the HQ Air Force Engineering and Services Support Branch (RDCO), especially Senior Master Sergeant Carl R. Hollopeter, from the Instrumentation Section for the outstanding professional support provided during these tests.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.


JOSEPH L. WALKER
Chief, Fire Technology Branch

RICHARD M. HANES, Colonel, USAF
Director, Engineering and
Services Laboratory


ROBERT J. MAJKA, Lt Colonel, USAF
Chief, Engineering Research Division

TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION.....	1
	A. OBJECTIVE.....	1
	B. BACKGROUND.....	1
	C. SCOPE.....	3
	D. APPROACH.....	3
II	PERSONNEL EGRESS SYSTEM.....	5
	A. OVERVIEW.....	5
	1. EGRESS IDENTIFICATION SYSTEM.....	7
	2. BREATHING SYSTEM.....	9
	3. PERSONNEL ACCOUNTING SYSTEM.....	17
	B. SMOKE TESTING.....	21
	1. TEST NUMBER 1.....	22
	2. TEST NUMBER 2.....	23
	3. TEST NUMBER 3.....	23
	4. TEST NUMBER 4.....	23
	C. HALON TESTING.....	24
	1. TEST SETUP.....	24
	2. SAMPLING PLAN.....	24
	3. CONCENTRATION ANALYSIS.....	27
	4. TEST RESULTS.....	30
	D. RESULTS AND CONCLUSIONS.....	31
	1. RESULTS.....	31
	2. CONCLUSIONS.....	32
III	FUEL-SECURING SYSTEM.....	36
	A. OVERVIEW.....	36
	B. PREPARATION.....	36
	C. SYSTEM DESIGN AND OPERATION.....	38
	D. AQUEOUS FILM-FORMING FOAM (AFFF).....	42
	1. LAYOUT TEST.....	42
	2. BURNBACK RESISTANCE TEST.....	42
	E. CONCLUSIONS.....	43

TABLE OF CONTENTS
(CONCLUDED)

Section	Title	Page
IV	CONCLUSIONS AND RECOMMENDATIONS.....	44
A.	CONCLUSIONS.....	44
1.	PERSONNEL EGRESS SYSTEM.....	44
2.	FUEL-SECURING SYSTEM.....	45
B.	RECOMMENDATIONS.....	45
APPENDIX		
A	AMETEK AUDIO TESTS.....	47
B	TEST PLAN FOR FIRE PROTECTION DETECTION HARDENED AIRCRAFT SHELTER (HAS).....	55
C	HALON 1211 CONCENTRATIONS VERSUS TIME CURVES.....	81
D	TEMPERATURE PROFILES FOR HAS HALON 1211 DISCHARGE.....	89
E	PURCHASE DESCRIPTION, PERSONNEL EGRESS SYSTEM FOR HARDENED AIRCRAFT SHELTERS (HAS).....	95
F	PURCHASE DESCRIPTION, FUEL-SECURING SYSTEM FOR HARDENED AIRCRAFT SHELTERS (HAS).....	105

LIST OF FIGURES

Figure	Title	Page
1	HAS Personnel Egress System.....	6
2	Egress Arrow Detail and Layout.....	10
3	Halon Cylinder Placement and Halon Sampling Locations.....	26
4	Fuel-Securing System.....	37
5	Fuel Securing - Nozzle Deflection.....	40
6	Fuel Securing - Spray Distribution.....	41
B-1	Plan Review of Test Shelter and Personnel Egress Layout.....	61
B-2	Fuel-Securing Test Layout.....	63
B-3	Test Organization.....	68
C-1	Halon Concentration Versus Time Curve, HAS Front, 1-Foot Level.....	82
C-2	Halon Concentration Versus Time Curve, HAS Front, 5-Foot Level.....	83
C-3	Halon Concentration Versus Time Curve, HAS Side, 1-Foot Level.....	84
C-4	Halon Concentration Versus Time Curve, HAS Side, 5-Foot Level.....	85
C-5	Halon Concentration Versus Time Curve, HAS Rear, 1-Foot Level.....	86
C-6	Halon Concentration Versus Time Curve, HAS Rear, 5-Foot Level.....	87
D-1	Temperature Profiles for Halon 1211 Discharge, Thermocouples 0-3.....	90
D-2	Temperature Profiles for Halon 1211 Discharge, Thermocouples 4-7.....	91
D-3	Temperature Profiles for Halon 1211 Discharge, Thermocouples 8-11.....	92
D-4	Temperature Profiles for Halon 1211 Discharge, Thermocouples 12-15.....	93

LIST OF TABLES

Table	Title	Page
1	BREATHING SYSTEM EVALUATION.....	15
2	SMOKE TEST SERIES.....	22
3	GRAB SAMPLE CONCENTRATIONS OF HALON 1211 INSIDE THE HAS.....	29
D-1	THERMOCOUPLE LOCATIONS FOR THE HAS HALON 1211 DISCHARGE.....	94

SECTION I

INTRODUCTION

A. OBJECTIVE

The objective of this effort was to develop: (1) a system which secures a jet fuel spill in a Hardened Aircraft Shelter (HAS), and (2) a system which permits egress of personnel from the HAS under fire-extinguishing concentrations of Halon 1211.

B. BACKGROUND

Hardened Aircraft Shelters are designed primarily for aircraft protection and turnaround. The shelter is designed primarily for one aircraft; however, cases have occurred in which two aircraft are stored in the shelter concurrently. Typical shelter construction consists of galvanized sheet metal reinforced by up to 3 feet of concrete. The shelters are rectangular, with a width of 80 feet, a length of 120 feet and an arched/domed roof about 37 feet high at the center. The shelters have concrete floors and are outfitted with all standard utilities and exhaust fan systems. The usual personnel exit from the shelter is through the personnel door, but the main door or the rear exhaust opening may also be used. The personnel door, at the side of the main door, is steel with a shaped protective steel structure outside of it for shrapnel protection. The personnel door is the primary exit for all personnel, under normal and emergency conditions. The main door is a heavy steel shell filled with concrete. It rides on wheels and is split in the middle so that both sides roll outward for opening. The main door also has a wheeled tricycle outrigger for stability. When the main doors are open, a winch can be used to pull aircraft backwards into the shelter.

The third possible emergency exit from the shelter is the port for engine exhaust gases at the rear of the shelter. The port has a steel door on the inside of the shelter. Outside of the shelter, the exhaust duct "Y's" into two ducts protected by embankments for shrapnel protection.

The functions performed in the shelter include standard aircraft maintenance and sortie generation servicing. Turnarounds consist of replenishing the fuel, consummables, and munitions on the aircraft. Under threat conditions, the aircraft turnarounds may be "hot". The number of personnel in the shelter to perform all the turnaround functions averages about 10. The potential hazards from fires in the hardened shelters are largely based on the flammable materials available (fuels, plastics, rubber, etc.) and the ignition sources (hot engines, exhausts, etc.). Supplementing the normal products of combustion as hazards in shelters are hazardous materials carried on aircraft such as hydrazine and extinguishing agents such as halons.

Until the new fire detection/suppression system is installed in exiting HASs, fire protection is provided by positioning a standby fire truck and crew within the shelter area complex. The existing method of providing fire protection does not include securing protection against fuel spills which may occur inside a closed shelter, nor does it provide any means to egress personnel from a smoke-filled shelter. The current practice for securing fuel spills inside a closed shelter is to deenergize the electric door fuel-opening system, pull the doors open with an external vehicle and dilute the spill with either water or aqueous film-forming foam (AFFF) agent. If the shelter fills with smoke or if visibility becomes restricted, a firefighter wearing a self-contained breathing apparatus (SCBA) would have to search the shelter for occupants. These practices are unacceptable for protecting personnel and mission-essential weapons.

The personnel egress test series involved three tests in which the HAS was completely filled with generated smoke and one test with an actual complete dump of Halon 1211. Four test subjects wearing SCBAs egressed the facility by following a system consisting of audible sounds, high-intensity lights, and a series of reflective and phosphorescent plastic arrows placed on the floor of the shelter. The smoke tests were conducted on 16, 18, and 20 September 1986, and the halon test was conducted on 22 September 1986.

C. SCOPE

The scope of this effort consisted of testing fuel spill securing and personnel egress systems for compatibility with the newly developed HAS fire detection/suppression system. The fuel securing system has the capability of being easily retrofitted. It is self-sufficient and manually operated and can accomplish its function without movement of any equipment or systems in the HAS. The personnel egress system is also self-sufficient and can guide individuals to one or more exits simultaneously. Integrated into this system is the assurance that each individual in the HAS can breathe safely for at least 5 minutes following discharge of halon. The scope of this effort further consists of developing fuel-spill-securing and personnel egress systems compatible with the HAS. The final product of the effort is this technical report which details all work accomplished. This report also includes drawings and general specifications.

D. APPROACH

The fuel-spill-securing system was approached from the initial standpoint of reviewing commercially available agents, with primary consideration given to a premixed AFFF agent. The minimum system size was assumed to be 300 gallons. Manual operation of the system without impingement on other shelter functions was imperative. Further, the system had to pass burnback resistance tests to validate its fuel-securing characteristics. In addition, it had to be environmentally acceptable and not hazardous to shelter equipment and operations.

The personnel egress system had to assure a safe and effective egress route for all shelter personnel during periods of heavily restricted visibility. The design of the egress system necessarily included supplemental breathing apparatus. The system design called for no specialized training nor any impingement on the normal daily tasks of shelter personnel. Finally, the system would include a personnel accounting capability.

The approach called for the full-scale testing of all of the above stated system characteristics, such testing to be accomplished in accordance with an Air Force approved test plan. The testing took place at Tyndall AFB in the two-thirds scale Third-Generation Shelter and included functional and system tests. Testing encompassed JP-4 fuel spills, smoke-filled shelter demonstrations, and one discharge of neat Halon 1211.

SECTION II

PERSONNEL EGRESS SYSTEM

A. OVERVIEW

The personnel egress system was viewed as a simultaneous effort involving investigation and testing of three distinct systems. The results of this effort were designed to provide: (1) a fully directional system of any auditory, visual, and tactile stimuli or any combination of these, which would permit the shelter occupant to locate and travel to a shelter exit safely and in a reasonable amount of time under Halon 1211 discharge conditions, (2) a compact, reliable, and easily donned breathing apparatus which would furnish clean air to the occupant for the time necessary to egress the shelter, and (3) a counting device which would reliably indicate the number of persons in the shelter at any time. NMERI awarded a subcontract to AMETEK Offshore Research and Engineering Division on 5 August 1986, to assist in the development of these concepts.

The emergencies for which the personnel egress system is being developed are those in which the halon system has been activated. The immediate effect of a halon release is a dense, white, foggy cloud. Visibility is reduced to almost zero. The halon concentration may not be overpowering, but personnel should leave the shelter as rapidly as possible to minimize contact with the halon. If a fire is involved, the interaction of the Halon 1211 with the combustion products can create a toxic, eye-burning gas consisting of hydrogen chloride, hydrogen bromide, hydrogen fluoride, bromine, and chlorine. In this case, personnel must be provided with a means to protect their eyes and respiratory passages along with a breathable mixture. If the fire incident has injured personnel sufficiently that they cannot leave the shelter, a means of determining the number of people in the shelter and their location is needed to assist the fire department in rescue attempts.

Figure 1 shows the three subsystems which comprise the personnel egress system and their relative need, depending on the type of incident. A first need in a fire emergency is to separate oneself from the danger by making a rapid exit from the building. If a rapid exit is not possible within a

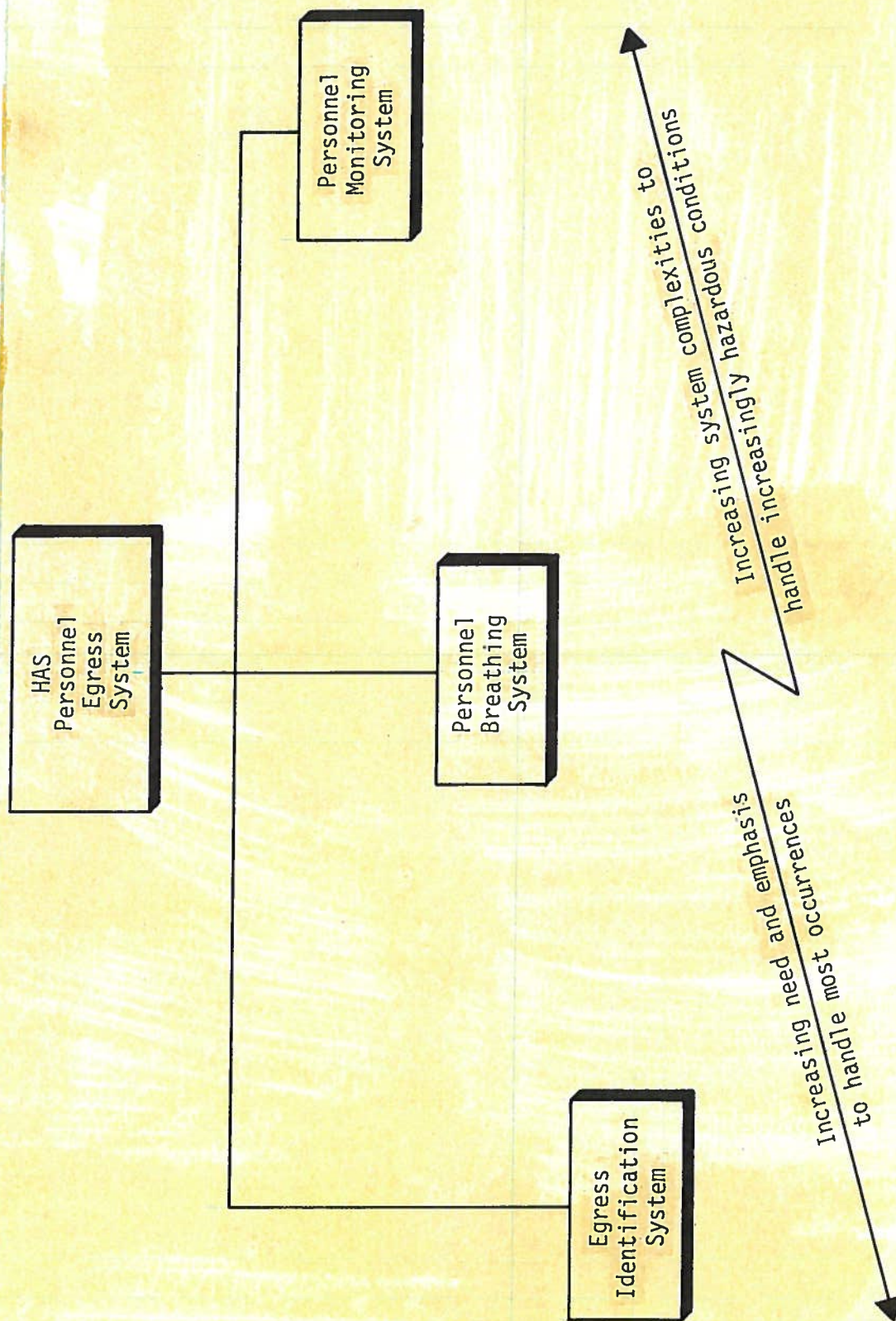


Figure 1. HAS Personnel Egress System.

short time, additional protection must be added for personnel safety in the form of breathing apparatus and/or eye protection equipment. If the emergency has caused extensive damage and personnel injury, the need for equipment will change, from that used by the individuals for exiting, to that used by rescue personnel to find and assist persons injured or overcome by smoke. These three systems are shown in Figure 1, with the need increasing to the left to accommodate most occurrences and the increased system complexities increasing to the right to handle more involved hazardous conditions. This is similar to standard procedures used in commercial buildings, where every building requires an exit marking system and very few have a personnel accounting system.

The investigation into the egress identification system involved review of commercial hardware on the market, purchase of representative audible alarms, and testing of the alarms for their adaptability to exit marking. The personnel breathing system investigation primarily involved a marketing review of equipment and an evaluation of applicability. Investigations into personnel monitoring systems involved comparing various system concepts and the advantages and disadvantages of each. Investigation of each of the systems is described below.

1. Egress Identification System

The objective of the egress identification (exit marking) system in the HAS is to direct personnel to an exit door in the event of a fire emergency and possible halon release in the HAS. Videotapes of fire and halon release tests in simulated shelters were reviewed for background information relating to the fire environment in the HAS. The videotapes of HAS FPS proof-of-concept tests indicate that visibility is drastically reduced and the general environment in which the marking system must operate would contain flames, smoke, halon fog, halon exhaust noises, and general commotion.

The human senses that can be used to assist an individual in leaving a building are sight, touch, and hearing. Data sources searched during this study included miscellaneous sources such as the Braille Institute for the Blind, information from vendors and manufacturers, and literature in the

AMETEK Corporate Library in Paoli, Pennsylvania. None of the sources revealed any meaningful work accomplished in this area of concern.

The most direct route to providing an exit system for the HAS was to concentrate on audible alarms. Numerous alarms are on the market, but they are primarily designed to provide a startling noise heard universally throughout a designated area. Few alarms on the market have been designed to project a directional sound that people can follow, but since many more are available on the market, a selection can be made among them to choose those more conducive to directionality of sound.

The Braille Institute was not aware of any hardware or alarms available for use by sight-impaired people. Their one recommendation was that the audible alarm should be of a beeping or intermittent nature. Most manufacturers emphasized the importance of selecting a proper signal, based on signal function, ambient sound conditions, and area to be covered. For emergency warning, most manufacturers of alarms were concerned that the noise be sufficiently startling, loud, and different to convey the need for immediate action. Little work regarding directionality of the sound has been done.

Preliminary tests were conducted at AMETEK to direct initial steps in specifying audible systems for the HAS. Subsequent tests were conducted at the HAS in an attempt to adjust and fine-tune the alarms to the shelters. The findings from the tests at AMETEK showed that low-frequency, intermittent sounds from an alarm placed over a doorway provided the best directionality of sound and one that people could follow to safety. These tests are summarized in Appendix A.

Further, it is more important that the noise be heard throughout an area. Literature searches show that periodical articles on alarms in buildings have been published, but the articles do not specifically address the question of using the alarm to direct personnel to an exit.

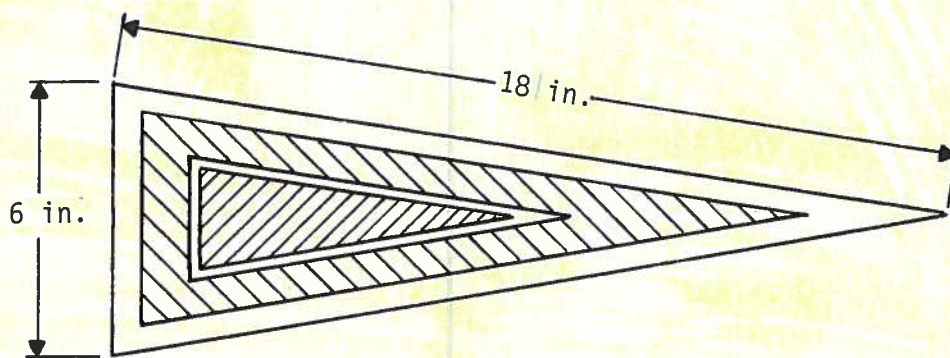
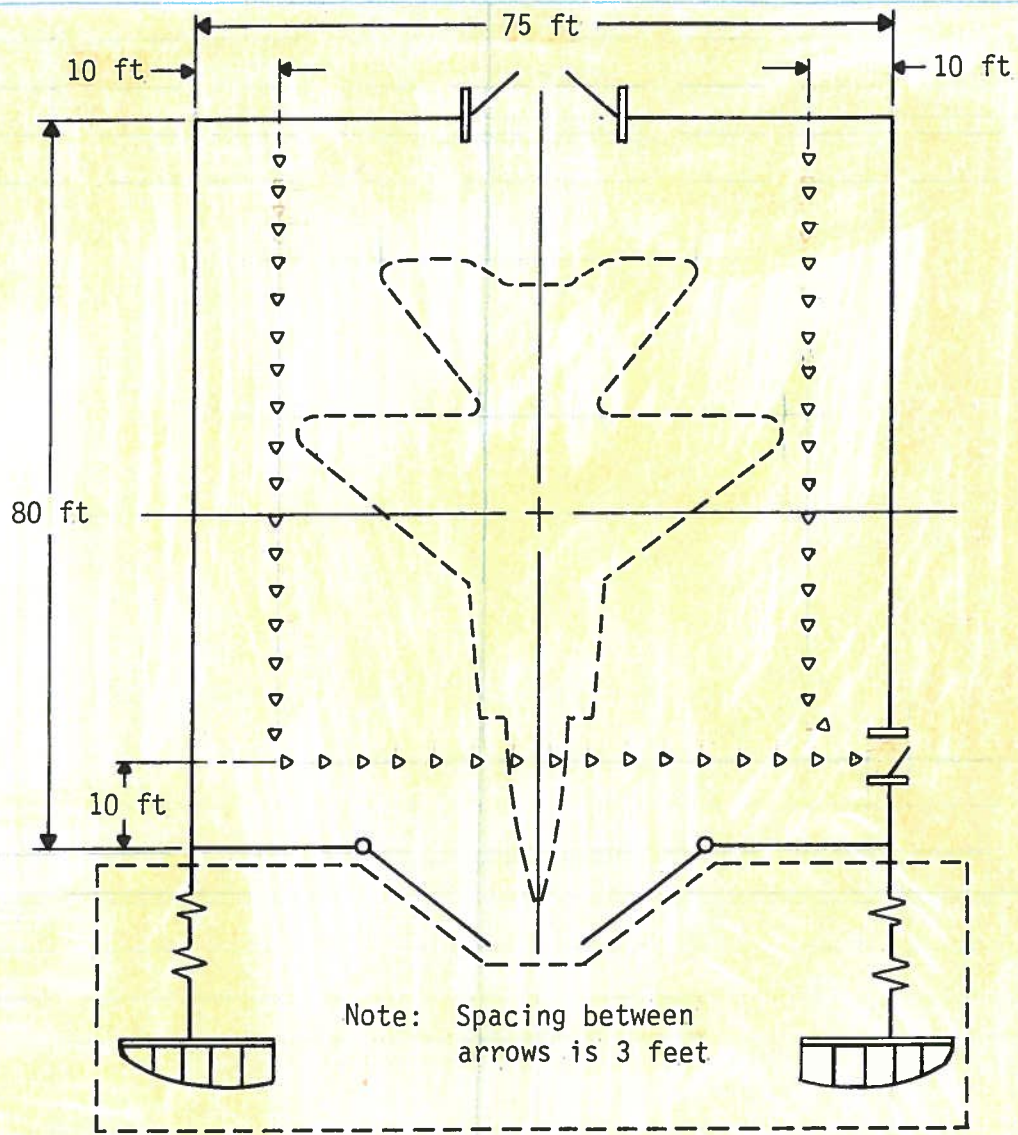
Marking systems for each of the senses (sight, touch, and hearing) were considered during the evaluation. Visual sensing was brought into the study by testing a warning horn which had an integral strobe light. The test was intended to show the impact of using both sight and hearing concurrently to determine the direction to an exit.

The concept considered by AMETEK for using the sense of touch was a series of lines on the floor leading to the exit. The lines could be an adhesive tape with dots and arrows on it that the person could feel to keep on track and going in the right direction. A review of commercially available equipment did not find any tapes with raised dots or arrows. Something of this nature could be built into the floor or be added to it. A method could be made for testing by using existing antiskid and phosphorescent floor marking tapes. The phosphorescent tape could provide visual assistance to find an exit, while the antiskid tape would provide a tactile difference between the concrete floor and the tape for ease in following it. Also, tapes are available that have printed arrows on them.

A combination of these tapes laid parallel to one another on the floor in lines leading to exits could be used for testing. NMERI continued this investigation by developing and constructing directional arrows to be placed on the HAS floor in a defined egress pattern. The triangular arrows were constructed of 1/8-inch clear plastic, 18 inches long and 6 inches wide at the base. The arrows were outlined with 1-inch strips of either phosphorescent tape or reflective tape. A smaller triangle of rubberized friction material was placed within the outline. The arrows were assembled and placed on the floor of the HAS as shown in Figure 2. The arrows were placed 3 feet apart, tip to base, with alternating phosphorescent and reflective arrows along the exit path. In addition to offering visual and tactile egress direction, the arrows were expected to provide a controlled egress corridor which would lead the egressing individual around the parked aircraft and along a path which represented an egress lane to be kept clear of obstacles at all times. This approach and its results are described later in this report.

2. Breathing Systems

A series of breathing concepts ranging from respirators to air supply and oxygen-producing systems were reviewed to determine their effectiveness and applicability to this project.






-  Phosphorescent or Fluorescent Tape
-  Friction Material
-  Clear Plastic, 1/8-inch Thick

Figure 2. Egress Arrow Detail and Layout

Breathing system equipment appearing to meet the requirements for use in the HAS are either on the market or in the development stage. Two systems found during the review of commercial equipment were an air capsule with a stored air container and an oxygen-producing breathing bag. Either of these systems can be used currently or can be made usable with minor modifications.

a. Respirator

A typical respirator is an air purifying/filtering device intended to improve particulate material from the air with the proper filters and cartridges installed in the respirator, some gases can be removed from the airstream. Masks that cover the nose and mouth to regulate the way air is inhaled and exhaled are available from many commercial sources. Filters and cartridges in the masks are replaceable to protect against various dusts, mists, or vapors. These masks are versatile, economical, and durable. Typically, they have soft rolled edges for comfort and good sealing characteristics. Exhalation valves preclude any contamination from entering the facepiece except through the filters. The various filters and cartridges can be color-coded or marked for easy identification to match the mask with the particular contamination hazard.

Since the respirators do not produce oxygen, they can only be used in cases where there is sufficient oxygen (20 percent) to sustain life. For this reason they are usually not recommended for use in firefighting applications. Also, the filters and cartridges must be sized or selected to match the particular hazard; one cartridge cannot do all jobs.

b. Gas Mask, Chin-Style

Gas masks are the next step up from the respirator. The gas masks have greater capacity to handle large volumes of contaminated air because a canister is attached to the mask rather than a small cartridge and filter. The gas masks also provide protection to the eyes, an important factor in cases of contact with many toxic materials.

Typical gas masks have soft, pliable facepieces designed to conform to most face sizes and shapes. Materials are heat- and damage-resistant, and the units are designed for easy donning and quick adjustment. Modern gas masks have one-piece lenses similar to diving masks for good visibility. The breathing air passes over the lens as it is inhaled, to reduce fogging of the lens. Some gas masks come packaged in small plastic cases which hold the mask and canister.

Gas masks purify the inhaled air so they can only be used where sufficient oxygen (20 percent) exists. They are generally suitable for ventilated areas with relatively stable concentration levels of contaminants. They should not be used in confined spaces or where oxygen deficiency and high gaseous concentrations may occur.

Stable concentrations are important because canisters can generally purify no more than 2 percent concentration of toxic gases and vapors by volume. This limitation on gas masks can be problematic where vapor and gas concentrations are constantly changing. Canisters are prepared to purify specific ranges or types of contaminating gases. While canisters are easily color-coded or marked for identification, the contaminants in the air must be known for proper matching of canister to gas.

The chin-style gas mask has a small canister that screws directly into the connector on the facepiece for easy replacement. The system is easy to use, with only a few minor neck motions being hampered.

c. Gas Mask, Chest-Style

The chest-style gas mask is identical to the chin type in many ways. The primary advantage of the chest type over the chin type is that a larger canister can be attached to the mask for longer duration of use. The disadvantages of the chest type over the chin type would be the added operations necessary to hook up the unit, its weight, and the fact that the breathing tubes can be snagged.

d. Self-contained Breathing Apparatus

A self-contained breathing apparatus is the choice of fire-fighters for protection from contamination and gases. The system provides a self-controlled environment that obviates the need to know the contaminating gases and allows use in oxygen-deficient atmospheres.

The units are all basically similar except for the size of the air storage cylinder, which determines the length of time the unit is to be in use. Typical ratings are for 1, 1/2 or 1/4 hours of use.

Typical components of the systems are cylinders, shutoff valves, bypass valve, pressure gage, injection nozzle, regulator, mask, audible alarm, and backpack frame straps. The units can weigh up to 35 pounds, depending on the size of the cylinder, and are somewhat cumbersome to don. Because they are more complicated, they are more expensive and require more training for use and more maintenance. Because of their size, it is not feasible for the individuals to wear them at all times, and they would have to be strategically placed in the HAS. This apparatus is considered a marginal option.

e. Emergency Egress Kit

A variation on the breathing apparatus equipment is a small unit available for short periods of use; it is similar to bailout bottles used by pilots. A typical unit can provide 5 minutes of use for emergency egress from hazardous environments. The unit is wall-mounted and is normally highly visible to allow instant access. It can be donned quickly, is simple to operate, and features single-use, disposable cylinders. The cylinders contain 28 percent oxygen-enriched air and can be easily replaced in the field. The emergency egress unit offers a full vision hood fabricated of clear polyurethane with a rubber neck seal. It also has a first-stage regulator, cylinder and manifold assembly, and case. The case can be canvas or injection-molded plastic.

Since these units are sufficiently bulky, wall mounting is suggested. They must be strategically placed in the HAS. This kit is also considered a marginal option.

f. Air Capsule

The air capsule is designed for one purpose: emergency escape. The unit consists of a transparent hood which can be placed over the head and into which breathing air flows from a storage source. The hood and air storage container are stored in a strong plastic case. The unit is removed from the plastic case, the start ring is pulled, and the hood is donned. The cool airstream is released above the forehead and flows directly onto the head, helping to reduce fogging and maintaining a cool atmosphere inside. No special nosepiece or mouthpiece is necessary. The entire hood is transparent to provide all-around visibility. If smoke creeps into the hood as it is being put on, the air flow will clear it up in a matter of seconds. There are no belts, straps, or valves to turn during installation.

The universal design fits all faces and the air flow obviates concerns of leakage. There is no need for concern about selecting the right canister to remove existing toxic fumes or whether the contamination level is immediately hazardous to life.

g. Oxygen-Producing Breathing Bag

A relatively new device for emergency escape use is a breathing bag that contains an oxygen-producing canister. The bag has a mouthpiece on it so the individual can breathe into the bag. A noseclip is clamped to the nose so that all breathing is through the mouth. The canister in the bag generates oxygen and removes exhaled carbon dioxide. The units are small and lightweight, allowing them to be hooked to the belts of all persons in the HAS for easy accessibility. They do not provide eye protection, but this is being actively considered for future development.

h. Breathing System Evaluation

Evaluations of the breathing system concepts are shown in Table 1. Review of the mission requirements and intended use of the breathing system shows several vital system characteristics. A primary requirement for the system is to protect personnel in the HAS in the event of a

TABLE 1. BREATHING SYSTEM EVALUATION.

	Respirator	Gas Mask	Self-Contained Breathing Apparatus	Egress Kit	Air Capsule	Oxygen-Producing Breathing Bag
SAFETY						
Eye protection	--	0	x	--	0	--
Respiratory protection	0	0	x	0	x	x
Protection against halon	--	0	x	x	x	x
Protection against particulates	0	0	x	x	x	x
Protection against hazardous materials	--	0	x	0	x	x
Oxygen-containing	--	--	x	x	x	x
USE						
Speed	x	x	--	x	x	x
Ease	x	x	--	--	x	0
Universality	x	0	0	0	0	x
Accessibility	x	x	0	0	0	x
PHYSICAL CHARACTERISTICS						
Size, bulkiness	x	0	--	0	x	x
Weight	x	0	--	0	x	x
Simplicity of design	x	0	--	0	x	0
Adaptability to movement	x	0	--	0	0	x

x Best; 0 Average; -- Poor

halon release whether or not it is associated with a fire. Thus, the system - ✓ should protect against halon concentrations in the air. A fire and its combustion products add two more important requirements: the breathing system must protect against smoke and oxygen deficiency and the toxic byproducts of halon combined with combustion products.

A halon release can occur at any time without warning, so the breathing system must be easily accessible to the personnel. The systems can easily be located near where the people work, but it is preferable to have a system that is worn by each worker. Experience in coal mines has shown that emergency breathing equipment must be with the worker at all times to be effective.

The review of the above, noting desired needs of the breathing system along with the evaluation summarized in Table 1, shows that either the air capsule or oxygen-producing systems would meet the needs of the Air Force. The majority of the Air Force needs can be met with existing commercial equipment or equipment in the prototype stage with few required modifications. Both the air capsule and oxygen-producing system should be further evaluated to determine which should be developed for future Air Force use.

i. Development Requirements and Risks

There are existing air capsule and oxygen-producing systems to guide the Air Force in developing a breathing system for use in the HAS. Development risk on this project is low and successful project completion is envisioned.

The requirements for the breathing system to be developed should include the following:

- Protection from halon
- Protection from smoke
- Eye protection
- Breathing air for use in oxygen-deficient environments
- Small package size

The development program to provide the Air Force with a beneficial breathing system should be done in the following steps:

1. Review system requirements.
2. Conduct a vendor search of similar systems.
3. Purchase similar systems and components for evaluation and review. Modify systems and subelements.
4. Establish evaluation criteria.
5. Select system concept design and develop specification.
6. Design system and procure prototype.
7. Test prototype.
8. Finalize design and procure production quantities.

This project has moved the development program through Step 5 above.

3. Personnel Accounting System

The objective of the personnel accounting system is to track the personnel entering and leaving the HAS and maintain a continuous record of the number inside the shelter. The number of people in the shelter would always be displayed at the entrance. If a major emergency or disaster occurred at the site, firefighters and rescue personnel arriving at the scene would immediately know how many people were still inside, which would greatly assist them in rescue operations.

Manual methods of accounting for the persons in the HAS can be implemented for minimal costs, but they can easily be defeated accidentally or deliberately. They generally have low credibility. Personal audio alarm devices are reliable and inexpensive. Fire departments have used them for several years. However, they are an additional piece of apparatus that the worker must wear and they will not indicate the number of people in the shelter. Highly accurate systems which could be relied on by rescue personnel would entail engineering and development risks, at considerable cost. While sensors to detect personnel are available, their capability to detect efficiently in a fire environment is not generally known. Likewise, circuits and systems to discriminate among the signals to determine when personnel enter or leave and to tally the number in the HAS would need to be

developed. Automatic personnel monitoring systems would promote the greatest safety for HAS workers and rescue personnel. Systems must be investigated and developed in more detail so that their cost effectiveness can be assessed. Potential concepts for personnel accounting, ranging from purely manual to complex monitoring systems, are briefly described here, along with the advantages and disadvantages of each.

a. Manual System

A simple manual system can be devised that consists of a series of numbers on a flipboard. Persons entering the HAS would flip up the next highest number on the board, and as they left, they would flip to the next lower number. In theory, the board would always reflect the number of people in the HAS. This system is extremely simple to operate, requires no engineering, and can be set up immediately. It can easily be reset to zero at the end of the day, when the shelter is empty, to correct for errors. One disadvantage of the system is that people will forget to flip a number when they go in or out. Another disadvantage is that, under emergency conditions, probably no one would flip a number when exiting. The firefighters would have to determine the number that successfully exited and compare it to the number on the board to determine the number still in the HAS. This adds a more time-consuming task to the rescue procedure. Also, the manual system only reflects the events at one door, which is problematic if personnel enter or exit by doors other than the personnel door. The manual system is sufficiently cheap and simple, however, and could be tried at a few locations with no risk and very little expense.

b. Personal Audio Alarm System

Although this is not an actual accounting device, it appears to offer an inexpensive, reliable alternative to actually counting the number of people. The device is a small (4 by 3 by 2 inches) pulsating, electromechanical annunciator which is worn on the belt. It emits a directional sound alarm of 90 dB or greater when switched by the wearer or when the unit is totally motionless for 25 seconds. The audio signal of this device would have to be tested for compatibility with the egress audio signal.

c. Detection System

The passage of people through a doorway can be detected by many different types of sensors and personnel can be electronically counted to provide a continuing record of the number of people in the buildings. An electronic system has the advantage of sensors at various doorways which can be wired into an integrated controls system that would compute the running balance and display it visually at all the doorways.

A wide range of sensors could be used in modes varying from semiautomatic to automatic. A semiautomatic system could rely on switches that are to be pressed at the doorway when it is opened. The actuation of the switch would be entered into the counting electronics. Another system could require the individuals to insert their identification badges into a slot at the doorway. This would both count and identify the individual entering or exiting. The technology for these systems is commercially used today in elevators and key lock systems. A major advantage of using the badges as a key is that the identification of persons in the HAS would be known. It is not foolproof, however. Once the door has been opened by one person, several other individuals could enter the HAS without tripping the counter. Once again, under emergency conditions it is highly unlikely that badges would be used or buttons pushed.

Fully automatic methods of detecting personnel are available. For example, photoelectric sensors can use an interrupted beam of light to detect passage of persons. Likewise, sensors can be built into identification badges to detect passage of personnel. These systems are used at retail store doors to provide signals when customers enter, and stores also place sensors such as the Sensormatic™ on unsold goods to prevent theft.

While the basic sensors described above are available, a discriminator circuit would have to be developed for use in the HAS. The sensors activate a signal that can be detected and counted electronically, but, in itself, an individual sensor cannot detect the direction a person is moving. An additional device such as an "up-down counter" can be used, along with a second detector unit to keep an instantaneous tally of net accumulation of objects passing through the monitored zone. The use of the

two sensors in a specific order would indicate the direction of travel and the total number of people or objects passing into a room could be added, while those leaving the room could be subtracted from the accumulated total.

This beam interruption method of counting can be subject to error. A person could enter the monitored zone, then leave without going past the second detector cell. A swinging arm or hand could add an erroneous signal. Two people passing through at the same time might not leave sufficient space for the beam interruption to be reset, and the two might be counted as one. While these and other fault sources could be guarded against, some degree of uncertainty still would exist for the system. It would have to be checked for correctness on a periodic basis and be resettable to the correct number of people in the HAS.

d. Monitoring System

Another concept in personnel accounting is to employ a system to monitor all persons in the HAS at all times. Each person authorized to enter would be given a badge that must be worn while in the HAS. The badge would contain a sensor that could be detected by surveillance equipment in the HAS. By having surveillance equipment located at several spots, the exact position of each sensor could be noted, using XY coordinates of the HAS floor plan. The position of each person wearing the sensor would be presented as a visual readout at each door. The main advantage of this system is the presentation of real-time data. Rescue persons responding to an emergency at the HAS would have the latest data on both number and locations of all individuals. Persons injured or overcome by smoke could be located. This could provide greater safety to the rescue crew in that they would not spend excessive time in a dangerous environment looking for injured people.

There are no disadvantages to this system except perhaps feasibility and cost. Not only must a system be defined, but it also must be error-free in an environment of smoke, fire, and halon. Sensors and detectors must be tested in the fire environment. Total system feasibility must be evaluated and determination of cost effectiveness must be made.

e. Concept Evaluation

The advantages and disadvantages of each of the concepts were discussed concurrently with the descriptions for each of the concepts above. In general, the manual, audio alarm, and semiautomatic systems could be incorporated into the HAS systems fairly easily, but they are not fool-proof and are subject to errors that could mislead rescue personnel. The automatic and monitoring systems would better perform the personnel accounting function, but would require some development, engineering, and testing before they could be deployed. A number of detecting and monitoring systems are currently in use in commercial industry. These systems could be reviewed to determine the ease with which they could be adapted to Air Force use. The development risk in attaining working hardware for a personnel accounting system is not high, but the cost of that hardware would probably exceed acceptable limits. Therefore, neither automatic detecting nor continuous personnel monitoring are considered candidates for further investigation.

B. SMOKE TESTING

The smoke testing was conducted in accordance with the approved test plan presented in Appendix B. Table 2 is a matrix that provides details of the smoke test series.

TABLE 2. SMOKE TEST SERIES.

Test No.	Date/Time	Smoke Production	Egress Stimuli
1	9-16-86/1000	One smoke generator 72 smoke grenades	Strobe High-intensity light
2	9-18-86/1000	Same as Test 1	Strobe, high-intensity light, horn reflective arrows, spaced at 6 feet
3	9-18-86/1400	Same as Test 1	Same as above, no horn
4	9-20-86/1000	Two smoke generators	High-intensity light, reflective arrows spaced at 3 feet, metal reverberation device. No strobes nor horn.

1. Test Number 1

In this test, the smoke generator was run for 12 minutes. Immediately thereafter the 72 smoke grenades were ignited. This took 2 minutes. Obscuration was not complete and all subjects were able to see for distances of 6 to 8 feet. Subjects 1 through 4 egressed the shelter at the respective times of 3.39, 1.24, 1.22 and 4.22 minutes. All subjects egressed by following the interior shelter walls. Subjects 1 and 4 saw the high-intensity light from an estimated distance of 25 feet from the door, while Subjects 2 and 3 saw the light from an estimated 10 feet.

2. Test Number 2

The smoke-generation sequence for this test was identical to that for Test 1, and obscuration conditions were similar. Egress times for subjects 1 through 4 were 19, 52, 50, and 29 seconds, respectively. This dramatic improvement in egress times is attributable to the addition of the phosphorescent and reflective arrows described in Section II. All subjects used the arrows as their primary means of egress. Subjects 1 and 4 thought the red (reflective) arrows were better, while Subjects 2 and 3 preferred the white (phosphorescent). All subjects agreed that the scatter of the strobe lights and the echo of the horn rendered them useless as directional devices. Subjects 1 and 4 saw the high-intensity light 15 to 20 feet from the door. Subject 2 did not see the light until he reached the door, while Subject 3 never saw the light.

3. Test Number 3

The smoke-generation sequence for this test was essentially the same as for Tests 1 and 2, except that the smoke generator was allowed to run for 22 minutes. Resultant obscuration was considerably greater. The egress times for Subjects 1 through 4 were 0.58, 1.15, 1.4, and 1.65 minutes, respectively. Because of the greater degree of obscuration, egress times increased. Subjects 1 and 4 used the arrows for egress, Subject 1 using the white and Subject 4 using the red. Subject 1 had to crawl to follow the arrows, while Subject 4 lost track of the arrows twice. This was probably because of the spacing and some imprecise alignment. Subjects 2 and 3 followed the wall for egress. The strobe lights pulsed together and were seen by Subjects 1, 3, and 4 at distances from 5 to 10 feet from the door. In these cases, however, the strobes were seen in a broad-range, pulsing context and were not useful from a directional standpoint. The high-intensity light was seen by Subjects 3 and 4 between 2 and 4 feet from the door; when seen, this light provided direction. No audio device was used during the test.

4. Test Number 4

Smoke was generated by two smoke generators which were allowed to run for 23 minutes. Obscuration was the most intense of all tests, with

visibility reduced to less than 2 feet. The spacing between the reflective arrows was reduced from 6 feet to 3 feet and a metal reverberation sound was produced by striking an empty 1-liter stainless steel sample bottle with a steel open-end wrench every 3 seconds. Subjects 1 through 4 egressed the shelter in 0.49, 0.80, 1.59 and 1.21 minutes, respectively. Subjects 1, 3, and 4 followed the walls to exit. Subject 2 used only the sound to get to the door, while Subjects 1 and 4 said the sound was helpful and Subject 3 did not hear the sound. None of the subjects found the arrows or saw the high-intensity light.

C. HALON TESTING

1. Test Setup

A Halon 1211 discharge system was installed in the Tyndall HAS for this test. The system consisted of four individual cylinders, each filled with 800 pounds of Halon 1211 and pressurized by nitrogen to 360 lb/in.². The cylinders were mounted on the interior walls of the shelter as shown in Figure 3. Each cylinder had two discharge nozzles, mounted 11 feet above floor level. Discharge of all cylinders was effected simultaneously with remotely activated solenoid valves.

The egress system was essentially the same as in previous smoke tests with the addition of a system of floor lights. Several strings of very small Christmas tree lights were connected to make a single strand of white lamps, 6 inches apart, placed directly over the arrows. All other aspects of the egress system were the same as in Smoke Test 4.

2. Sampling Plan

Halon concentrations were monitored at various locations in the shelter to better determine the egress requirements and the hazards to personnel in the HAS shelter during a full Halon 1211 discharge. Continuous monitoring of the Halon 1211 was accomplished with a Perco Model 113 halon/carbon dioxide analyzer, and grab samples were taken with evacuated 1-liter stainless steel sample bottles. Thermocouples were placed at each of the 12 sampling positions to continuously monitor temperatures at the heights at

which the samples were collected. Additional temperature data were obtained using thermocouples in place from previous HAS testing. Temperature data were collected to provide correction to the concentration data if such correction were necessary. The halon sampling was designed to provide information about exposure levels of Halon 1211 for personnel in the HAS, as well as those for a pilot in the cockpit of a hangared aircraft. The testing also provided information on the equilibration time and the density separation of the Halon 1211 in a closed shelter.

The sampling locations are shown in Figure 3. Three areas were chosen for sampling: two locations near the center of the shelter at the front and rear and one near the wall. The sampling locations at the center of the shelter (Areas 1 and 3) correspond to the nose and tail of the aircraft. The samples near the wall (Area 2) were taken in a walkway for personnel. Continuous sampling with the Perco analyzer was performed at 1 and 5 feet at each sampling location. Grab samples were collected at 1, 5, 10, and 15 feet and were remotely triggered by manual switches activating the solenoid valves on each set of sample bottles. The switches were wired to the solenoid valves so that there was one switch for each sampling time. The samples were collected at 30 seconds and 1, 2, and 5 minutes after the halon discharge began ($t=0$). The solenoid valves were opened for 10 seconds to ensure pressure equilibration within the containers. The 1-foot level was chosen to reflect the concentration present if an individual was incapacitated and horizontal on the floor of the HAS; it also represents the concentration at the fuel surface. The 5-foot level represented that concentration at nose and mouth level. The 10-foot level was that of cockpit and engine level, with 15 feet being the theoretical maximum protection height corresponding to the aircraft tail height. The expected equilibration time of the Halon 1211 throughout the shelter was 30 seconds after the discharge starts. One minute was chosen as the time a fire response team should arrive if on patrol, while 2 minutes was the time for response of the fire crew if it is not on patrol and in the firehouse. The time chosen for the minimum lifetime of the supplemental breathing apparatus to be supplied to personnel working in the shelter was 5 minutes.

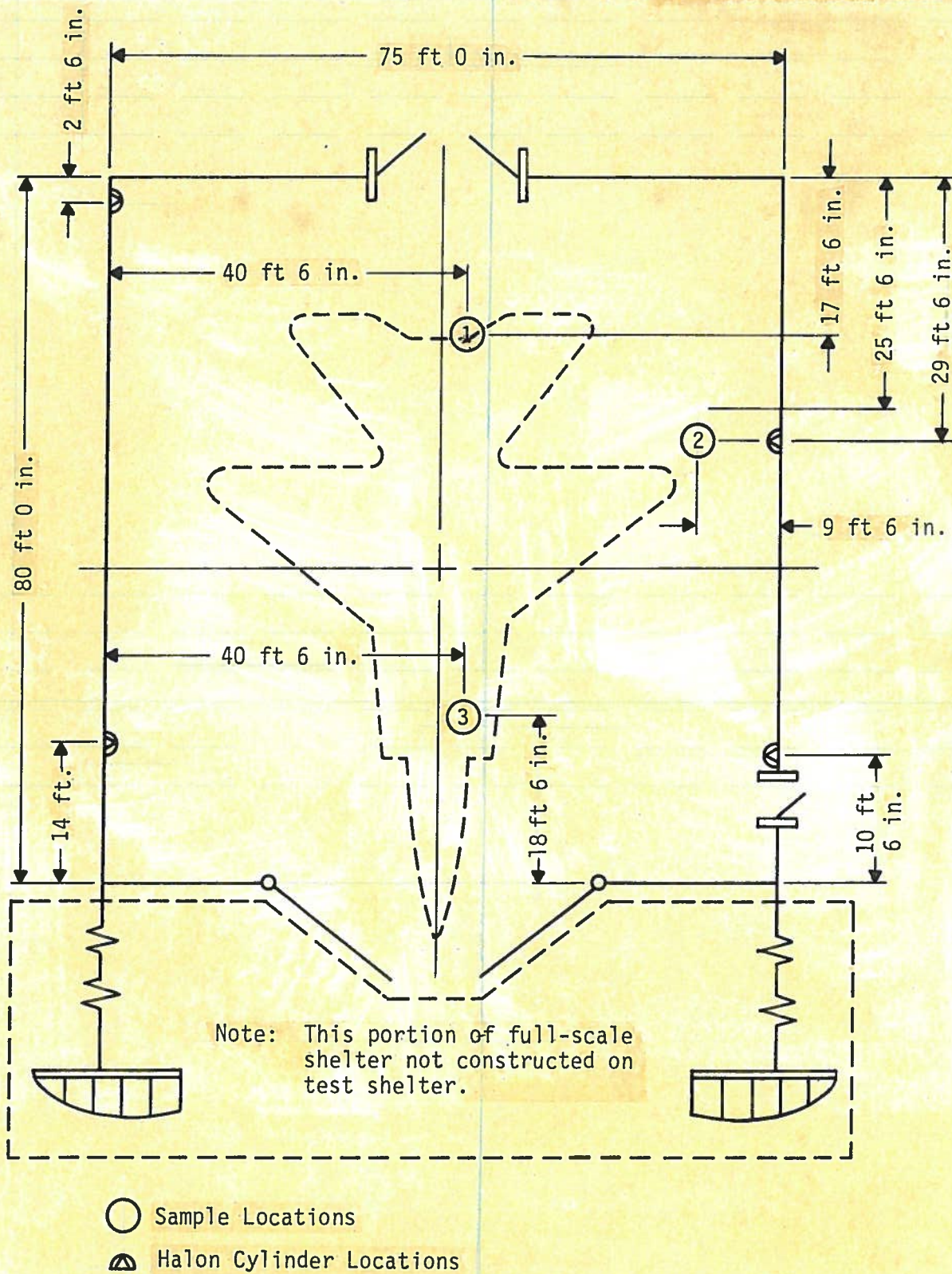


Figure 3. Halon Cylinder Placement and Halon Sampling Locations.

The grab samples were analyzed by gas chromatography on a Hewlett-Packard 5890A gas chromatograph (GC) with a 0.53-mm crosslinked stationary phase capillary column. The GC parameters for the Halon 1211 analysis were: column pressure, 27 kPa; column flow rate (He), 4.2 mL/min; total flow rate (column plus make-up gas), 30 mL/min; split vent flow rate, 80 mL/min; split ratio, 19.0; oven temperature, 35 °C isothermal; injection port temperature, 100 °C; detector temperature, 150 °C; detector, flame ionization. The 1211 vapor standard was prepared from an aliquot of the head space above liquified Halon 1211. Sample volumes of 5 μ L were injected from gas-tight glass syringes.

3. Concentration Analysis

Halon 1211 concentrations were determined during the HAS egress test by collecting grab samples of the atmosphere and by continuous monitoring with Perco analyzers. The Perco data provide information on the equilibrium concentrations in the HAS shelter, as well as complementing the grab sample data. Weather conditions were monitored at the time of the halon discharge to aid in interpreting the data. The temperature outside the shelter was 87 °F with a relative humidity of 55 percent. The barometric pressure was 30.10 inches of mercury and the wind was from the southwest (210 degrees) at 4 knots. The front of the HAS shelter faces 185 degrees south-southwest.

Two Perco analyzers were used and both were calibrated immediately before and after the test to check for any changes in the instrument response. The analyzers were also tested against each other for differences in measuring the same concentrations. Although the instruments maintained internal precision (± 1 percent) and linearity of response, the accuracy of the raw data was not reliable until flow correction. Calibration curves for correcting the Perco raw data were constructed by measuring the instrument response for each Perco at 0, 2, 4, 6, and 8 percent. The corrected data are shown in Figures C-1 through C-6 in Appendix C. The Perco data as the concentration changes in the shelter are not correct because of the mixing that occurs as the sample travels through the sample tube. However, as the concentration within the shelter equilibrates, the change in concentration due to mixing becomes negligible and may be ignored. The time from

introduction of halon into the sample tube to an observable response on the analyzers was between 30 and 40 seconds. Perco concentrations were monitored for approximately 30 minutes after the halon discharge.

The Perco equilibrium concentrations parallel the grab sample concentrations well, although the magnitudes are different. Concentrations at 30 seconds after discharging range from 1.6 to 7.8 percent, the highest concentration being measured at the rear of the shelter at the 1-foot level. However, the Perco data at 30 seconds may be less than the actual value because of the mixing as the sample moves through the sample tube. All of the Perco concentrations are increasing at 30 seconds, thus, equilibrium has not been reached. The Perco data suggest that equilibrium at the 1- and 5-foot levels is reached in less than 2 minutes. After equilibrium in the shelter is reached, the concentration data recorded on the Perco analyzer are valid. One minute after discharging, the concentrations have become more uniform, ranging from 4.5 to 9.6 percent. The higher concentrations are again found at the rear of the shelter and the density separation of the Halon 1211 with height is apparent. After 2 minutes, the concentrations range from 7.1 to 9.7 percent. At 5 minutes, the concentrations are nearly uniform, ranging from 8.2 to 9.4 percent. After 5 minutes the concentrations remained fairly consistent (6.5-9.0 percent) until the doors of the HAS were opened at 10 minutes after the discharge. Concentrations decreased rapidly from approximately 8 percent to less than 3 percent in 3 minutes.

The grab sample data do not require reduction before analysis; however, some of the data are suspect because of leaky bottles and differences in the degrees of vacuum between sample bottles. Sample bottles suspected of leaking were reevacuated after analysis and checked for vacuum integrity. These data are noted in Table 3. In Table 3, the concentrations of Halon 1211 determined from the grab samples are given. The concentrations after 30 seconds range from 6.8 to 8.2 percent below 10 feet and from 1.0 to 4.2 percent at 15 feet. The variation is most likely the result of incomplete mixing of the cold, denser halon and the warmer air inside the shelter. At the front of the HAS, the percentage of halon varies from 7.1 percent at 1 foot to 2.9 percent at 15 feet. The temperatures parallel the

TABLE 3. GRAB SAMPLE CONCENTRATIONS OF HALON 1211 INSIDE THE HAS.

Sample Height, feet	Front	Rear	Side
Concentrations at 30 seconds, percent			
1	7.1	8.2	7.6
5	6.8	8.0	^a 0.00
10	^a 0.027	7.5	6.2
15	2.9	1.0	4.2
Concentrations at 1 minute			
1	6.6	^a 0.00	6.7
5	7.1	5.8	5.5
10	6.1	5.9	5.4
15	3.5	2.4	2.5
Concentrations at 2 minutes			
1	7.8	^a 0.24	3.8
5	6.9	6.3	6.3
10	5.0	^a 0.00	^a 0.25
15	1.5	2.2	1.8
Concentrations at 5 minutes			
1	6.1	5.4	6.3
5	6.9	5.4	3.3
10	3.7	^a 0.1	1.5
15	0.4	^a 0.00	1.0

^aBottles did not hold vacuum before sample collection.

concentrations quite well. Temperature profiles of the HAS halon dump are illustrated in Figures D1-D4 in Appendix D. Below 10 feet the temperature dropped from 91 °F at the time of the discharge to 59 °F 30 seconds later. The temperature at 15 feet dropped from 91 °F to 70 °F. The temperature at the side of the HAS did not drop as dramatically as the temperature at the front, but the measured concentrations at the side are similar to those at the front of the shelter. The concentration of 4.2 percent at 15 feet was the highest of the three sample locations, but this location was nearest to the Halon 1211 release. At the rear of the shelter, the highest concentrations of Halon 1211 were measured along with the sharpest decreases in temperature. The temperature at 1 foot did not drop to that of the other levels, although the concentration was the highest measured at 8.2 percent. At 1 minute after the discharge, the halon concentrations became more evenly distributed and were more uniform at a given height. The concentrations below 10 feet were similar, but there was a large difference at 15 feet. This was evidenced as well in the difference in temperatures between 10 and 15 feet. The concentrations at 2 minutes reflect the density separation of the halon with height. Concentrations decreased at 15 feet and increased at the lower levels. At 5 minutes after the discharge, all concentrations were beginning to decrease and dropped below the 1-percent level at 15 feet.

4. Test Results

The complete discharge of the Halon 1211 took 15 seconds. Subjects were instructed to wait for approximately 10 seconds after the discharge was completed to begin egress. With the egress timing starting at the beginning of the discharge, Subjects 1 through 4 egressed the shelter in 1.0, 1.45, 1.72 and 1.20 minutes, respectively. Initial obscuration limited visibility to less than 6 inches, but approximately 10 seconds after completion of the discharge the visibility increased to 6 feet. Under these conditions, egress was relatively easy. All four subjects used the combination of the floor lights, arrows, and sound to egress. The floor lights and arrows were visible from a standing position and the subjects felt that they could have seen the arrows even if the floor lights had not been on. In all cases the subjects required the strobes and high-intensity light approximately 10 to 15 feet from the door. By this time, however, a firm egress direction had been established.

D. RESULTS AND CONCLUSIONS

1. Results

The testing of the egress identification system encompassed a wide variety of variables, incorporated in the testing in numerous different combinations. Before testing there were some reservations regarding the use of human subjects, but well-thought-out procedures and solid safety practices permitted the testing to proceed. Without human subjects, realistic conditions, and the inherent feedback, the testing could not have been considered a suitable measuring device for the effectiveness of the egress identification system. The different approaches to smoke generation provided a range of obscuration conditions which prepared the subjects well for the Halon 1211 discharge. Using the same subjects for all five tests enabled them to acquire more mental preparation and physical familiarization for each succeeding test; however, this did not bias the tests. Those persons normally exposed to an actual HAS halon discharge will be those who frequently work under high stress conditions and who are intimately familiar with the physical layout of the HAS.

The sequence of smoke tests also replicated the Halon 1211 discharge conditions well and provided a more solid foundation of performance assessment of the different facets of the egress system. Although the smoke could not actually simulate the dramatic temperature drop which accompanied the Halon 1211 discharge, feedback from the subjects did not indicate that the sudden temperature drop affected their egress.

The ability to track the actual egress, practically step-by-step, was invaluable in analyzing and meshing together the various candidate aspects of the egress identification system. The test subjects and their accompanying safety personnel were sincerely interested in the test series and understood its crucial significance. This led to honest and comprehensive feedback essential to tests of this nature.

2. Conclusions

The overall personnel egress system must be composed of an egress identification system, a personnel breathing system, and a personnel monitoring system, with the relationships of these three subsystems as depicted in Figure 1.

a. Egress Identification System

All test emphasis was placed upon the egress identification system with the following aspects of that system being explored through the test series:

1. Audio device
2. High-intensity light
3. Strobe lights
4. Directional arrows
5. Floor lights

(1) Audio Device. The AMETEK audio tests were well-conceived and extensive. However, the recommended Banshee II, Model B-1224-NB did not produce the desired directional results when tested within the HAS. The nature of the HAS interior produced excessive echo on all recommended settings. Once this occurred, several different approaches were attempted to produce an artificial, directional signal. One approach, that of striking a halon sample bottle with a metal wrench, produced a dramatically directional signal. Thus, a quick series of tests of this artificial device was performed. These tests confirmed that the sound was directional to a large number of personnel, and repeatable, and that it should be incorporated into the Halon 1211 test the following day. As can be noted from the specific Halon 1211 test results discussed previously, the metallic and reverberatory nature of the sound prevented the problems of echo, and cut through particulate matter generated by the smoke and Halon 1211. The automatic and repetitive generation of the sound must be further pursued.

(2) High-Intensity Light. This light was seen by test subjects at approximately 15 to 20 feet from the door under medium obscuration conditions (Tests 1 and 2), and 10 to 15 feet from the door in the Halon 1211 test. In all cases, it provided directional capability important for completion of the egress.

(3) Strobe Lights. In all cases the light from the strobes was highly scattered and did not provide the desired directionality. The strobes were usually seen close to the door, but by then the high-intensity light had been seen and was providing final egress direction.

(4) Directional Arrows. While time did not permit desired investigation or development of the arrows before the scheduled testing, they produced positive results despite their rough design and material selection. There are also several other materials which are in various stages of development and application consideration. Examples of these are systems using electroluminescence and microencapsulated lamps. These systems have the options of sequential strobing and monochromatic color selection for optimum smoke penetration. They can also be installed in such a way that certain desired levels of redundancy are achieved. Additional studies of the arrows would optimize their construction, placement and overall contribution to the egress identification system. One very important egress aspect provided solely by the arrows is the establishment of an identifiable egress pathway. Such a pathway around the actual aircraft can be kept clear at all times to provide unobstructed egress from the HAS. Even if the clear-width is restricted to 3 or 4 feet, the egress capability will be provided. In addition to the concepts of rapid and assured egress from the HAS, the egress identification system must also ensure safe and controlled egress. These latter two concepts were provided by the arrows more than any other aspect of the system. It is not felt that maintenance of such a clear corridor at all times would negatively affect daily HAS operations.

(5) Floor Lights. While the floor lights proved helpful during the Halon 1211 test, it was felt that their contributory value was not significantly higher than that of the arrows. The floor lights do not, in themselves, provide direction; they have to be strobe-sequenced or color-coded to do this. They would also have to be recessed into the floor and sealed to prevent exposure to water, fuel and oil. This would entail expensive installation and maintenance and could affect their reliability.

The egress identification system would be composed of three parts. The audio device would provide a directional stimulus throughout the HAS. The high-intensity light would provide positive final direction once personnel approached the door, and the arrows would provide a pathway free of obstructions for a safe and controlled egress.

b. Personnel Breathing System

An extensive study of available personnel breathing systems was conducted by AMETEK and is summarized in Section II of this report. The egress tests themselves indicated that 5 minutes of breathing time would be adequate to permit personnel to egress the HAS. Once this was determined, the next major criteria are noninterference, wearability when out of use, and capability of rapid donning. The oxygen-producing breathing bag appears to best fit most of the criteria requirements. While extensive research has revealed no such devices on the market today, such a device has been built and tested by the Mine Safety Appliances Research (MSAR) Corporation as a prototype. While this report does not constitute NMERI endorsement of the MSAR unit, its apparent merits are such that it should be subjected to the development process outlined in Section II.

c. Personnel Accounting System

A wide range of personnel accounting devices already exist or are ready for development. Again, this subject was well-researched by AMETEK and is summarized in Section II. The advantages and disadvantages of

a manual system, a detection system, and a monitoring system are discussed in depth. NMERI concurs with the AMETEK opinion that the costs and complexities of incorporating detection or monitoring systems would be unacceptable to the Air Force. Thus, an easy to use and well-placed manual system, possibly combined with a personal audio alarm device, is recommended, along with the in-theatre command emphasis necessary to ensure its conscientious use by operations and maintenance personnel.

SECTION III

FUEL-SECURING SYSTEM

A. OVERVIEW

The fuel-securing application and storage system consisted of a 300-gallon capacity water storage tank containing a premixed 3 percent solution of AFFF. The AFFF met the specifications of MIL-F-24385C. The storage tank was mounted above the floor on the right rear wall of the test shelter. The fuel securing agent was expelled by pressurizing the main tank with dry nitrogen from two high-pressure nitrogen cylinders mounted directly beneath the main agent storage tank. Agent was discharged from the main tank through a 1 1/2-inch galvanized pipe connected to a hose reel mounted on the wall below the two nitrogen cylinders. A hard-hose, 1-inch-diameter hand-line 100 feet long was connected to the hose reel. Agent was applied from a constant 30 gallons/minute flow fog nozzle recommended for use with AFFF solutions (Figure 4).

B. PREPARATION

A complete fuel securing storage and dispensing system was designed and constructed for this test. Therefore, several preparatory operating and experimental tests were required to properly determine the optimum system operating features. The main points for consideration were as follows:

1. The need to apply fuel-securing agent evenly at 0.025 gallons/ft² over an area of 8520 ft² (the area of a third-generation aircraft shelter);
2. The need to visually determine what areas of the fuel spill have been secured and what areas have not;
3. The decrease in flow efficiency from the pressure loss by friction;

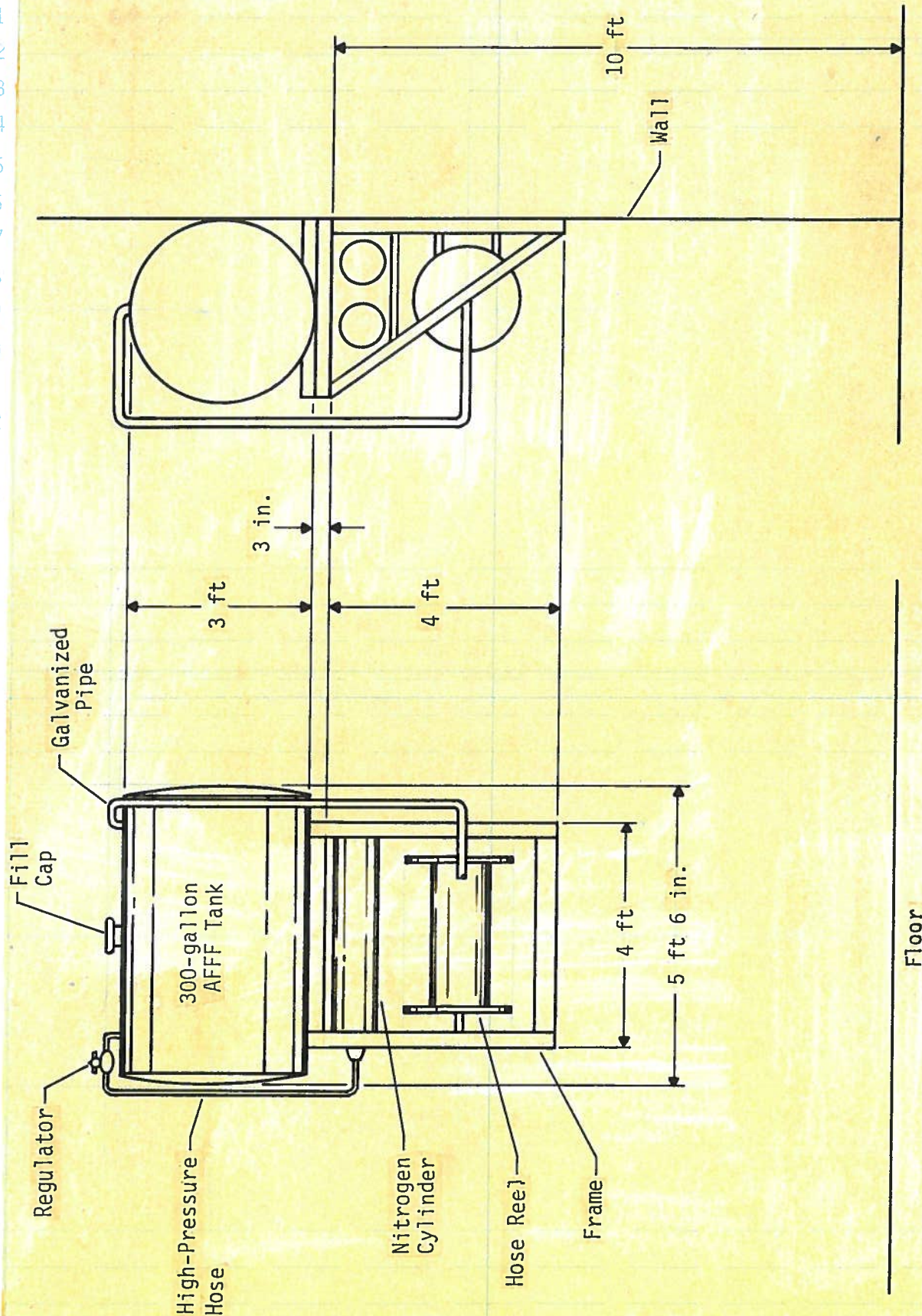


Figure 4. Fuel-Securing System.

4. The adverse reaction of semitrained personnel to strong nozzle reactions to large flows and pressures;

5. The optimum angle and degree of the fog spray pattern for proper application of the agent.

C. SYSTEM DESIGN AND OPERATION

The 300-gallon main storage tank size was determined by first calculating the exact agent amount required, which is $0.025 \text{ gallons/ft}^2 \times 8520 \text{ ft}^2$ (maximum area to be covered), or 213 gallons. Because the system is intended for use by semitrained personnel, and because it would be used in an area subject to many obstacles, a 40-percent factor was added as compensation for potential agent waste.

The need to avoid interfering with the existing shelter floor space necessitated hanging the tank and its related parts. The rear wall was chosen because of its relatively central location and the need to have a firm support base for the heavy weights anticipated. The fuel securing agent itself consisted of 300 gallons weighing 8.35 pounds per gallon, or 2502 pounds, with the tank, nitrogen cylinders, hose reel, hose, and supporting stands adding an additional 800 pounds, for a total weight in excess of 1 1/2 tons.

Three means of expelling the stored agent were explored. Friction loss made free-flowing the agent impractical. Pumping the agent from the tank would require a sophisticated and expensive mechanical pump and/or drive system, both considered impractical. Pressurizing the tank was determined to be the most feasible and least expensive method. The optimum tank pressure was found by experimenting with various nozzle designs. The final nozzle chosen was a 1-inch base, variable fog pattern nozzle. The nozzle would normally provide a constant 30 gallons/minute flow at a recommended 100 lb/in.^2 base pressure. Through experimentation the best fog pattern was obtained at a base nozzle pressure of 140 lb/in.^2 . To obtain this pressure at the nozzle, the system operating pressure was regulated to 165 lb/in.^2 static tank pressure. Flowing pressure at the hose reel was 155 lb/in.^2 with the 5 lb/in.^2 difference being the result of friction loss from the

galvanized piping. An additional 15 lb/in.² was lost through friction in the 100-foot by 1-inch handline hose, which left a constant nozzle base pressure of 140 lb/in.². The 140 lb/in.² produced an output of 34 gallons/minute. The increased pressure and quantity resulted in the markedly increased efficiency of the fog pattern. The AFFF droplets produced excellent aeration and resultant foaming.

The nozzle ranged in patterns from straight stream (0 degrees) to a full fog of 90 degrees. The most natural stance of a person using this nozzle for its intended fuel-securing purpose is in an upright position with the nozzle held in the right or left hand. The optimum nozzle deflection position angle is downward approximately 25 degrees from perpendicular to the body (Figure 5).

Experimentation determined that at this position the fog pattern at a spray angle setting in excess of 30 degrees tended to break up and scatter solution droplets randomly. At a spray angle of 20 degrees the stream had good consistency and a controlled application was possible. The effective agent application distance was 9 feet 6 inches. Agent expelled beyond this distance broke up severely. Little solution was applied to the 4-foot semicircle immediately in front of the nozzle, as fog nozzles at a 20-degree spray angle are not capable of covering this area. The person applying the agent sweeps the nozzle from side to side in a 140-degree arc, so that, with a 20-degree spray angle, a semicircle with a diameter of 19 feet and a depth of 5 1/2 feet will be covered. This equals 117 ft² of area (Figure 6). This area requires the even application of 5.8 gallons of solution to secure a fuel surface at 0.025 gallons/ft². The nozzle is discharging 0.57 gallons/second; therefore, 5 seconds of application are required to secure this area. At the pressure and rate of flow of the chosen nozzle, approximately 5 seconds are used to swing the nozzle through a 140-degree arc and cover the 117 ft² area. Therefore, two full swings of the nozzle, in a stationary position, would be sufficient to secure this area. For larger areas, the operator swings the nozzle while moving forward approximately 1 1/2 feet, providing an overlapping pattern and a sufficient 0.025 gallons/ft² coverage. The time required to totally discharge the required 213 gallons and fully secure a complete third-generation shelter at a flow of 34 gallons/minute is 3 minutes, 13 seconds.

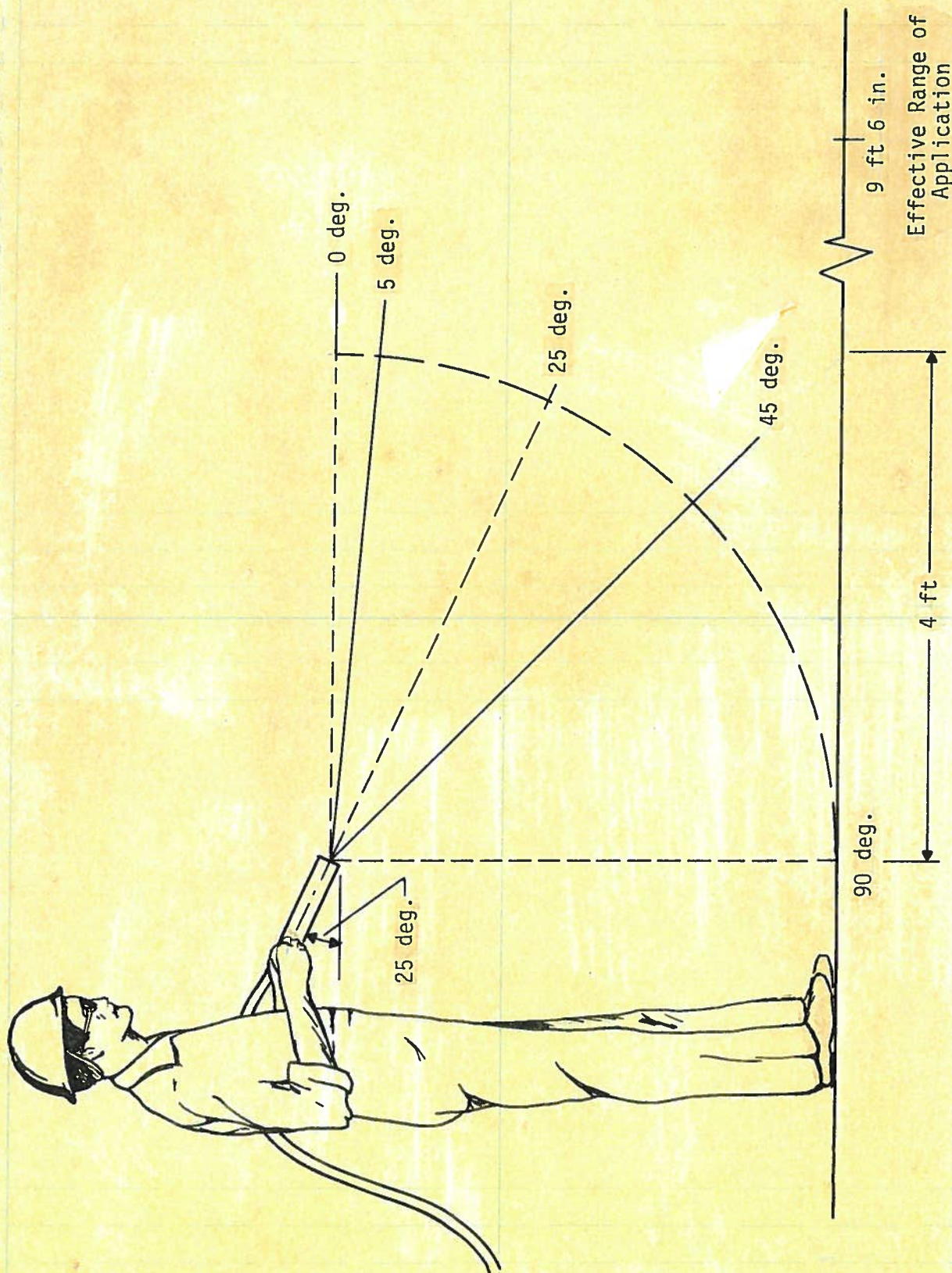


Figure 5. Fuel Securing, Nozzle Deflection.

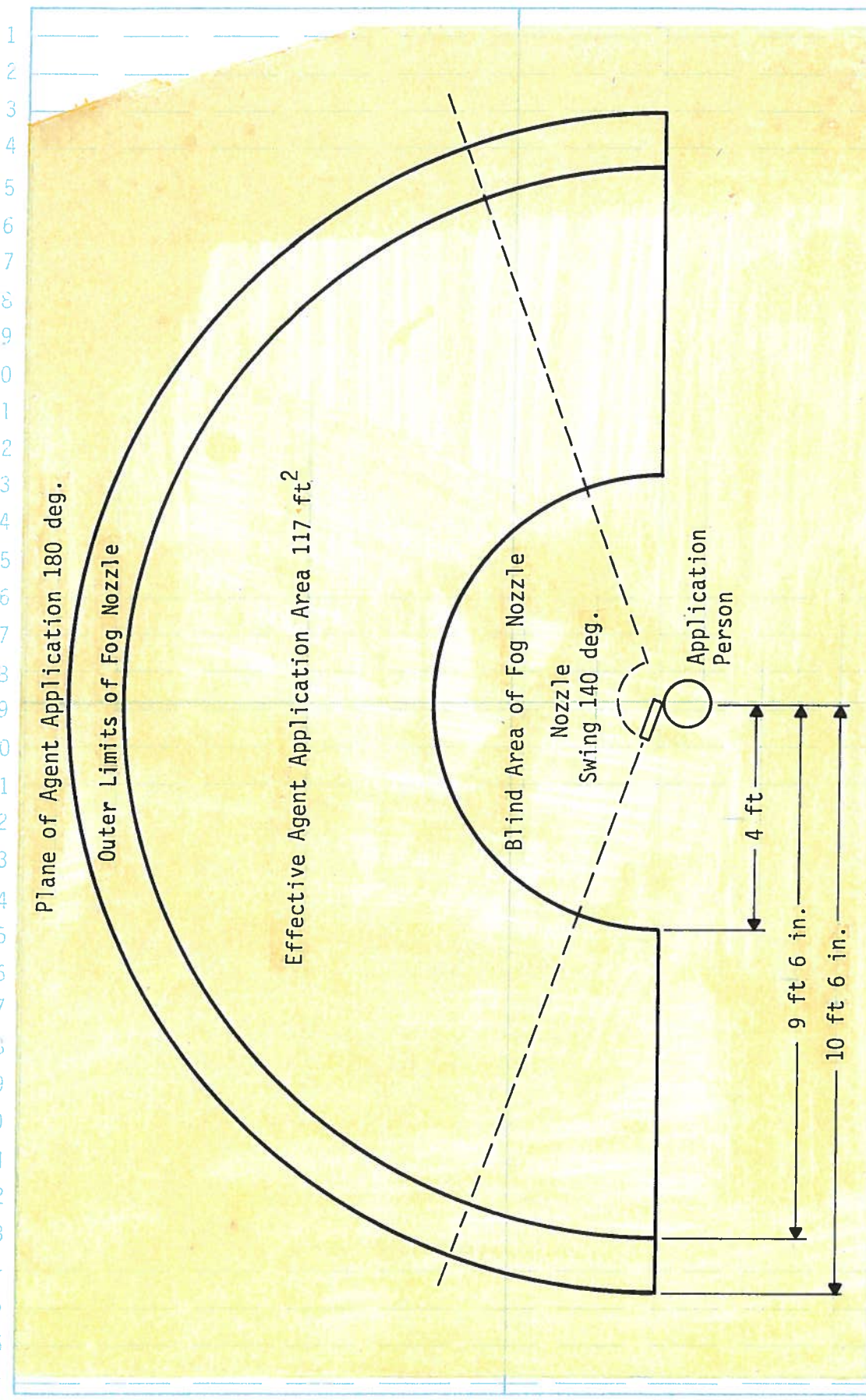


Figure 6. Fuel Securing, Spray Distribution.

D. AQUEOUS FILM-FORMING FOAM (AFFF)

1. Layout Test

Two hundred and eighty gallons of water were placed in the agent tank. A test solution was prepared consisting of 97 parts water and 3 parts pure 3-percent AFFF. The mixture was agitated and a portion was extracted and read on an industrial fluid tester hand-held refractometer. The refractometer was scaled from 0-30 with the exact 3-percent premix AFFF test solution reading 3.5. AFFF was added to the water tank and agitated until the tank samples also optically read 3.5 on the refractometer, assuring a precise 3-percent AFFF premix solution.

After the full amount of the AFFF solution was dispensed over the shelter floor, a flammable wand was passed over each of the test pans in the order and locations shown in the Test Plan, Appendix C. The wand was passed over every pan at a rate of approximately 1 ft²/s. This testing was conducted in three consecutive cycles. The individual cycles took 3.54, 3.26, and 3.61 minutes to complete, respectively, for a total of 10.41 minutes. During this time, the agent which covered each pan prevented ignition of the fuel. These results indicate that the amount and concentration of agent applied to the shelter floor were sufficient to prevent burnback for at least 10 minutes.

2. Burnback Resistance Test

During the layout test, a burnback resistance test was conducted on the 3-foot by 7-foot pan in the center of the shelter (see Figure B-3, Appendix B). With respect to the amount of agent and the size of the pan, this test necessarily deviated from the typical "stovepipe test" described in UL 162, Sections 18.20 and 18.21. Fifteen gallons of JP-4 fuel were placed in the pan, ignited, and allowed to result in a fully developed fire. The fire was then extinguished with a 5-second spray of the AFFF solution. This is a solution amount of 2.85 gallons and an area application rate of 0.136 gallons/ft². Immediately after the fire was extinguished, the stovepipe was placed in the pan, 1 foot from the sides and one end. The foam was removed from inside the stovepipe, the JP-4 was ignited and allowed to burn

for 1 minute, and the stovepipe was then removed. At the end of 5 minutes, the size of the fire had expanded to 9 ft². This would appear to indicate that the test passed the UL 162 criteria of a fire expansion of less than 10 ft². While the fire was prohibited from expanding on three sides by the sides of the pan, on the open side, where it had 5 feet to expand, it only expanded 1 foot during the 5-minute burn. This led us to conclude that the burnback resistance test was successful, particularly considering that foam was applied for only 5 seconds instead of the 3 minutes specified by UL 162.

E. CONCLUSIONS

The fuel-securing system developed and tested under this project fulfills all system requirements necessary for successful operation in the HAS.

1. The system provides a more than adequate amount of agent and incorporates a reasonable safety factor.
2. The system is simple to operate and unobtrusive, and can be effectively operated without requiring movement of any items within the HAS.
3. Because the system employs AFFF, it does not present toxicity hazards to operators, nor will it degrade any ecosystem in and around the shelter.
4. The system can be operated without adversely affecting shelter operations or increasing hazards to equipment or personnel assigned to the shelter.
5. Technically and mechanically the system is simple. It can be built, installed, and maintained in a cost-effective manner.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Personnel Egress System

The personnel egress system must be made up of three interacting, complementing subsystems: (1) the egress identification system, (2) the personnel breathing system, and (3) the personnel accounting system. The most difficult and complex of these subsystems is the egress identification system; therefore, the greater part of project effort was dedicated to the development of this system. An absolute requirement for this system was the complementing actions of overall directional stimuli and an established, identifiable egress pathway. Egressing personnel must be provided with an unobstructed egress path that is as direct as possible. It is further thought that the arrows described previously can provide this path, and that operations and maintenance activities can be carried out in the HAS in such a way that they do not obstruct this established path. If personnel attempted to proceed directly to the overall audio or visual stimuli, the chances of their direct pathway being obstructed by an aircraft, start cart, weapons carrier, or fuel truck, for example, would be high and could cause confusion, frustration, and injury and/or incapacitation. Thus, the egress identification system is considered, within itself, a complementing system. The effective interactions of the facets of this system are imperative in securing the safe, controlled, and reliable egress of HAS personnel in less than 3 minutes after the full or partial discharge of the Halon 1211 system. The 3-minute egress time was selected and specified in the Purchase Description (Appendix E) because the actual tests conducted have proven it to be a reasonable, attainable egress time.

Extensive market research and limited physical inspection of available products indicate the need for further pursuit of an appropriate oxygen-producing breathing bag to fulfill the requirements of a personnel breathing system. The time requirement for this system of 5 minutes is designed to provide a 67-percent safety factor over the required egress time of 3 minutes.

Personnel accounting systems range from very basic manual tabulation devices to highly sophisticated systems which can plot the exact position of personnel and even verify access and security clearances. A thorough evaluation of existing systems from cost and practicality standpoints indicates that the basic manual system best meets the needs of the overall personnel egress system.

2. Fuel-Securing System

The 300-gallon AFFF system as designed, constructed, installed, and tested fulfills all system requirements of agent distribution and fuel securing in the HAS. The system is mounted and operated in an easy and economical manner which does not interfere with other shelter functions. It is a technically and mechanically simple system which presents no safety, health, or environmental hazards.

B. RECOMMENDATIONS

1. The Military Purchase Descriptions attached to this report as Appendices E and F should be reviewed and processed.

2. Additional studies should be undertaken to:

a. Develop an economical and reliable design of an audio device which will replicate the directional metal reverberation sound successfully employed in the Halon 1211 discharge test.

b. Establish the most practical design and material selection and attachment method for the directional arrows. Consider wearability, maintainability, maintenance, and life cycle costs, along with optimum materials and placement designs.

c. Further investigate the potential and optimum design of the oxygen-producing breathing bag. Consider packaging and safety factors and conduct additional and realistic tests.

APPENDIX A

AMETEK AUDIO TESTS

Since no information on using sound to locate exit doors in an emergency was found during the literature search, it became necessary to obtain empirical data. A series of tests was planned and conducted to substantiate an audible exit marking system. This Appendix discusses the purpose of the tests, the test articles, the tests performed, and findings and recommendations.

A. PURPOSE OF TESTS

The purpose of the tests was to obtain information from several individuals on alarm sounds, loudness, locations, etc., to answer the following questions.

- Which sounds do people feel they would follow in an emergency?
- Which sounds are more directional?
- Where at the doorway should the alarm be placed?
- What are the effects of back-ups/alternative alarm methods such as strobe lights?

B. TEST ARTICLES

The guidelines in selecting the test articles were time constrained. The need for acceptable and easily available audible systems dictated selecting the test articles from commercially available equipment.

The test articles selected were:

- Banshee II, Model B-1224-NB
- Edwards Vibrating Horn, Model 873-G1
- Fike Strobe Horn, Model 20-049

The Banshee II was selected to obtain a comparison of different sounds. The Banshee II is a solid-state electronic sound device capable of a multitude of distinctly different sounds at a level of 100 dBA at 3 meters. If jumpers are placed across terminals on a terminal strip, the Banshee II can emit 15 different sounds or combinations of sounds including continuous wailing, sweeps, and intermittent sounds.

The Edwards vibrating horn was selected to evaluate vibrating horn type alarms and the ability to project the sounds to specific areas. The Edwards horn comes with a removable projector for directing the sound so that effects of projectors could be tested. This horn also has an adjustment to adjust sound level over a 26 dB range from 78 to 104 dB at 10 feet. The Fike Strobe Horn was selected for tests relating to the complementary effects of sound and light alarms. The horn is a vibrating type with an output of 97 dBA. The light is a Xenon flash tube with an intensity of 1 candela and a flash rate of 50 flashes per minute.

C. DESCRIPTION OF TESTS

The audible alarm tests performed include:

- Sound Preference Test
- Horn/Projector Directionality Test
- Horn/Strobe Test
- Sound Location Test

The tests were conducted in the AMETEK shop area. The floor plan of the open areas in the two rooms used are 79 to 63 feet and 60 by 80 feet for the assembly room and machine room, respectively. These sizes are in the range of the HAS test building at Tyndall AFB. The shop floors are concrete. The walls are Sheetrock™ and the ceilings are open-rafter flat roofs, approximately 12 feet high. The walls and ceilings of the AMETEK shop would be considerably more sound-deadening than the steel-lined walls and domed ceiling of the HAS.

All tests were conducted in ambient air during daytime hours. No smoke tests could be conducted at the facility and no extraneous noises were introduced into the tests. The results obtained must be considered with regard to the following occurrences.

- Sounds being deadened because of halon
- Sounds of halon flowing into the HAS
- Sounds being deadened because of smoke
- Fire sounds
- Other emergency sounds and alarms
- Explosions
- Miscellaneous voices and other noises
- Echoes off steel walls and ceilings

Each of the tests is described in the following sections.

1. Sound Preference Test

The Sound Preference Test was conducted in the assembly room using the Banshee II audible alarm. The unit was set up so that quick wiring connections could be made to select from 12 different sounds. Eight tests were conducted, using six different individuals. The alarm was mounted with the horn axis vertical for two tests and horizontal for the remaining six tests. The test participants included various age groups, both men and women. Two people participated during each test sequence. One person was located directly in front of the alarm at about 30 feet distance. The other person was also about 30 feet away but off axis from the horn by about 30 degrees. The people were asked to close their eyes and slightly disorient themselves by moving and rotating themselves. Each alarm sound was played for 10 seconds and the people were asked to respond on their data sheets as best they could to the following questions:

- How easy was it to locate each sound?
- Was the sound something you would follow?
- Was the sound discernible enough to follow?

The test results showed that continuous siren-type sounds were more difficult to locate.

Intermittent or beeping sounds seemed to allow the ear to pinpoint the sound more easily and with greater accuracy. Higher frequency sounds resound and echo, more making them more difficult to locate than lower frequency sounds. The Banshee II sounds in the order selected most for best directionality are high pulse, sweep pulse, sweep, wow, and chirp. Being off axis from the alarm or having the alarm pointed 180 degrees from the individual did not appear to affect the directionality of the sound.

2. Horn/Projector Directionality Tests

The horn/projector directionality tests were conducted in the assembly room, using the Edwards horn. Three individuals were used in this test with each person subjected to two tests. The first test had the horn without projector mounted on the wall at eye/ear level. The second test had the projector on the horn. In both tests, the people were positioned at spots 45, 70, and 180 degrees off axis from the centerline of the horn. The people would close their eyes, slightly disorient themselves, and then try to locate the signal as it was operated for about 10 seconds.

Sound loudness was also reviewed with the Edwards horn, which can be adjusted from a low level of 78 dB (approximately speech level) up to 103 dB at a distance of 10 feet. In the relative quiet of the AMETEK shop the low alarm sound levels were unacceptable. Subjectively, the loudest sound was considered best and all tests were conducted at a maximum level of 103 dB. The tests showed that the sound from a vibrating horn appears to be multidirectional. The direction of the horn could be missed by up to 90 degrees and different participants missed the location at different locations in the test. Adding the projector did not significantly add to the directionality of the horn. The test results are somewhat scattered but it could be concluded that the horn was operating as designed. That is, it permeated every area of the building to warn individuals and it was really not important in most cases to know where the sound was coming from. The sound would have been even more difficult to locate in a building having steel walls with more echoing.

3. Horn/Strobe Test

The horn/strobe test was conducted in the machine room using the Fish Horn/Strobe alarm. The purpose of the test was to determine whether a visual strobe signal would complement an audible signal. An additional feature of this test was to note any preferred height location above the floor where the marking alarms should be placed. The height locations used were 18 inches above the floor, at eye/ear level, and at a height equivalent to above a personnel door. The participants in the test stationed themselves at locations of 20, 40, and 60 feet from the alarm for each of the selected heights. The first test at each position was to note directionality of the horn sound with the eyes closed.

The tests were repeated at each position starting with the participants' eyes closed, and then open, to see whether the strobe light added any immediate information about where the alarm was located. Three persons participated in this test.

The testing indicated that the best location for the audible alarm was above the door. This was more pronounced when closer to the alarm. The results are somewhat inconclusive because the area used for testing had equipment in it that seemed to direct the sound. The addition of strobe lights as found on this standard Fisk component did not seem to add significantly to the locatability of the alarm. In fact, it seemed that the audible portion directed the individual more to the light on the alarm. The tests were conducted during the day in a building with many windows, which would somewhat reduce the effects of a strobe light, but perhaps not much more than a fire would. If anything, the strobe seemed to be more effective when it was located within 1 to 1 1/2 feet from the floor.

4. Sound Location Test

The purpose of the sound location test was to demonstrate the ability of individuals to walk directly to a sound source, using only the sense of hearing. The test was conducted in the machine room and three persons participated. The Banshee II alarm was located at a height equivalent to the top of a doorway and was set to the sweep pulse sound.

The participant was positioned about 50 feet from the alarm and was asked to disorient himself by closing his eyes and rotating himself. The alarm was then turned on and he was to keep his eyes closed and walk to the alarm.

The time to traverse the 50 feet varied from 20 to 30 seconds. Once a person got on track of the sound, the route of the sound was fairly straight. The sound was channeled by the equipment in the room by the way the individuals moved to the sound. This test shows that the sweep pulse setting can be used to direct people to a specific location based on use of hearing only.

D. FINDING AND RECOMMENDATIONS

The important finding relating to audible signals and strobe light marking of personnel exits from the test conducted at AMETEK are as follows:

- The audible signal should be pulsating or an intermittent sound. Lower frequencies are better. The higher frequencies tend to resound and echo more.
- A dB level of at least 100 at 10 feet should be the minimum used. Room sizes can make a difference in the sound level needed, as can the contents, which can muffle and channel sounds. The walls and ceiling materials will affect the echoing in the building.
- The audible alarm should be located above the personnel exit door.
- The standard strobe light addition to the commercial alarm to form a horn/strobe combination does not significantly add to the ability to locate the device.
- A strobe light seems to be most beneficial if located near the floor. This would probably hold true in a fire environment where the smoke rises. It would need additional testing in a halon environment where the halon lies close to the floor.
- A number of variables in a fire environment were not tested at AMETEK. These included effects of fires, explosions, yells and other noises, and the sound-deadening effects of halon and smoke.

The recommended equipment and procedure for an audible exit marking system for the HAS testing at Tyndall AFB is based on using a Banshee II, Model B-1224--NB. The unit shall be placed above the personnel exit door. It shall be adjusted and calibrated to the shelter by testing the unit with the personnel who will be in the shelter in advance of the smoke and halon tests. The sounds to be tried in the shelter are the high pulse, sweep pulse, sweep, wow, and chirp, in that order. Before the smoke and halon tests, the personnel are to be made aware of the sound they are to follow. ✓

APPENDIX B
TEST PLAN
FOR
HARDENED AIRCRAFT SHELTER
SUBTASK NUMBER 3.06-5
PERSONNEL EGRESS AND FUEL SECURING SYSTEM
PREPARED BY
THE NEW MEXICO ENGINEERING RESEARCH INSTITUTE
FOR
THE AIR FORCE ENGINEERING AND SERVICES CENTER

TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION.....	58
II	PARTICIPATING ORGANIZATIONS.....	59
III	DESCRIPTION OF TESTS.....	60
IV	LOCATION AND SITE DESCRIPTION.....	65
V	SCHEDULE OF EVENTS.....	66
VI	TEST ORGANIZATION.....	67
	ANNEX	
	1. Countdown Sequence of Events.....	69
	2. Communications Plan.....	72
	3. Safety Plan.....	73
	4. Engineering Support Plan.....	77
	5. Instrumentation Plan.....	78
	6. Photographic Support Plan.....	79

SECTION I INTRODUCTION

A. OBJECTIVE

The objective of this effort was to develop a system which allows the securing of jet fuel which might be spilled in a HAS and an assurance system that permits the egress of personnel from the HAS under fire/extinguishant condition.

B. SCOPE

This test plan establishes procedures for testing fuel-spill securing and personnel egress systems, both of which must be compatible with the newly developed HAS fire detection/suppression system. The fuel-securing system shall have the capability of being easily retrofitted, and it shall be self-sufficient, manually operated, and capable of accomplishing its function without requiring the movement of any equipment or systems in the HAS. The personnel egress system must also be self-sufficient and be capable of guiding individuals to one or more exits simultaneously. Integrated into this system will be the capability to assure that each individual can breathe safely for at least 5 minutes.

C. BACKGROUND

Until the new fire detection/suppression system is installed in existing HASs, the only fire protection is provided by positioning a standby fire truck and crew within the shelter area complex. The existing method of providing fire protection does not provide securing protection against fuel spills that may occur inside a closed shelter, nor does it provide any means to egress personnel from a smoke-filled shelter. The current practice for securing fuel spills inside a closed shelter is to deenergize the door opening electrical system, pull the doors open with an external vehicle and hose down the fuel with either water or AFFF agent. Should the shelter become filled with smoke or visibility become restricted, a firefighter wearing a self-contained breathing apparatus would be required to search the shelter for occupants. None of these practices is acceptable for protecting personnel and mission-essential weapons.

SECTION II
PARTICIPATING ORGANIZATIONS

1. Air Force Engineering and Services Center
Project Officer - Mr. Bryce Mason
Instrumentation - SMSgt. Hollopeter
Engineering Support - MSgt. Lavigne
2. Environmental Health
Bioenvironmental Engineer - Lt. Shelton
3. 325 Combat Support Group
Fire Department - Chief Stokes
4. Air Defense Weapons Center
Ground Safety - Mr. Parsons
5. University of New Mexico Engineering Research Institute (NMERI)
Principal Investigator - Mr. John Centrone/Dr. Dennis Zallen
Construction - Mr. Bill Dees

SECTION III

DESCRIPTION OF TESTS

A. TEST SPECIMENS

A single line drawing of the second-generation shelter (test site) is shown in Figure B-1. The shelter is constructed to two-thirds scale of a third-generation shelter, and of standard materials, i.e., corrugated steel elliptical arches covered with 14 to 16 inches of concrete. The floor is concrete with a 0.5-inch slope toward the front doors. A 6-inch concrete dam has been constructed around the perimeter of the shelter floor to prevent any spillage of fuel to the surrounding ground. The interior of the shelter is lighted with ten 1500-watt lamps. The front face of the shelter is skinned with high-gage corrugated metal. Two large hinged doors have been installed in place of the standard sliding hardened shelter doors shown outlined in Figure B-1. This modification will not affect the test results, as the tests will be conducted with the doors closed and compensations made for the two-thirds scale.

B. MATERIAL AND STRUCTURAL PROPERTIES

Generated smoke and Halon 1211 will be used to totally flood the shelter during the egress tests. Aqueous Film-Forming Foam (AFFF) will be used during the fuel securing tests.

C. INSTRUMENTATION AND PHOTOGRAPHY

Each test will include data on temperature and gas concentration. The data will be collected by thermocouples, grab samples, and evacuated cylinders. The photo coverage will be both 35-mm still and VCR. The photography will be synchronized with the other data collection.

Still photography will be required in the form of color slides and black and white positives to document the pretest setup and posttest results.

D. TEST PREPARATION

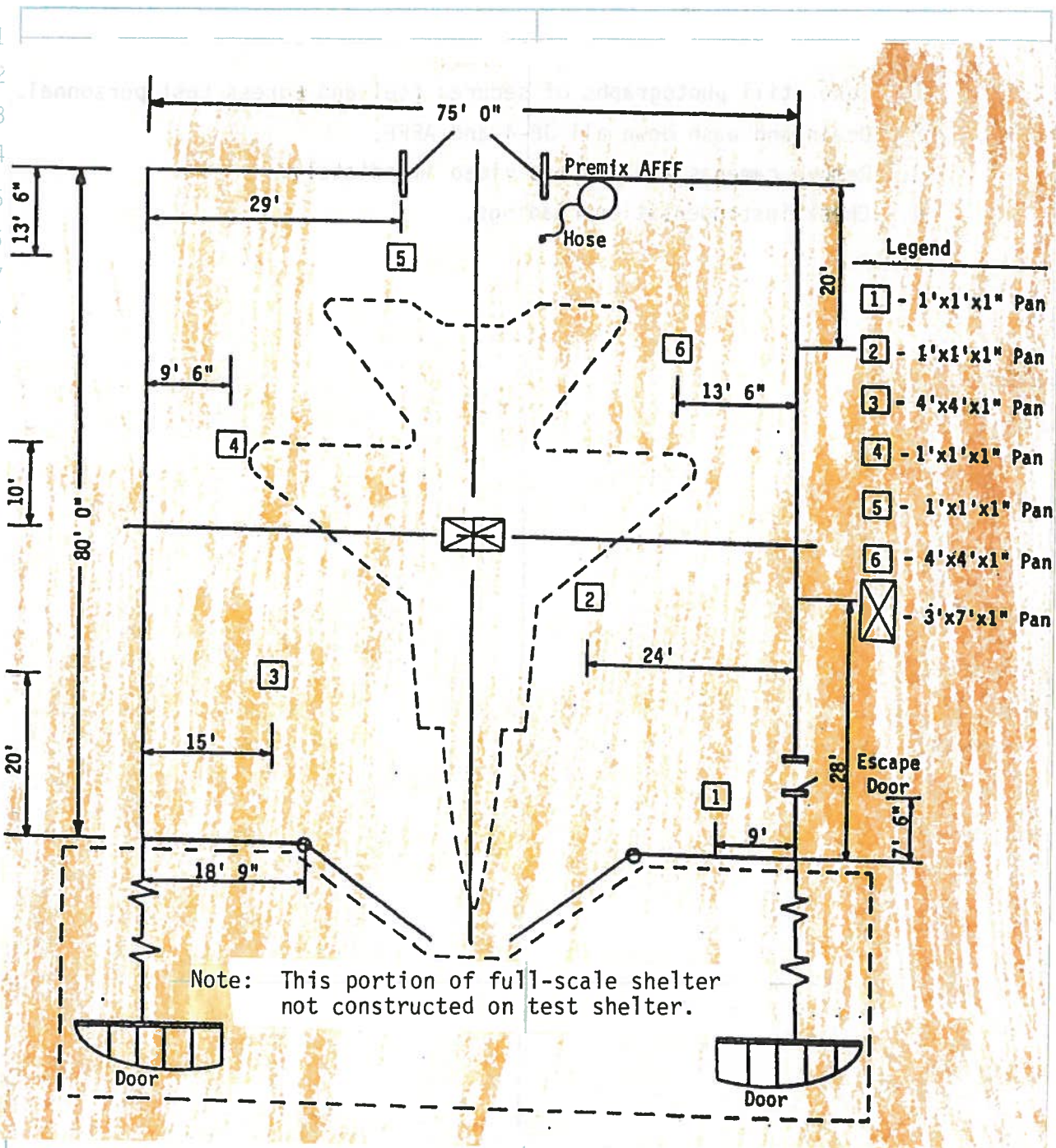
The general arrangement for a typical egress test is shown in Figure B-1. Before each test, the physical components of the HAS facility will be checked to assure their ability to support testing of the fuel-securing and personnel egress systems. Preparation for the individual test series will proceed as follows:

1. Install components of each system.
2. Install thermocouples and gas collecting devices and test for functioning.
3. Position and protect cameras.
4. Take pretest still photographs.
5. Evacuate nonessential personnel from inside the shelter.
6. Position either 150-gallon fuel supply or four test and four safety personnel for appropriate test.
7. Conduct final check of cameras and instrumentation.
8. Conduct countdown and either spill fuel or flood shelter with smoke or Halon 1211.
9. Activate smoke extraction fans if personnel egress does not appear to function effectively within 15 minutes after test start.

E. TEST EVENTS

Four individual tests will be conducted to evaluate the effectiveness of the fuel-securing and personnel egress systems.

1. The fuel-securing system (Figure B-2) shall establish the effectiveness of several different agents for securing any fuel spill; however, a premixed AFFF agent shall be given primary consideration.
2. The personnel egress system shall ensure an effective egress route during periods of restricted visibility when the exits cannot be detected with the naked eye.



Note: Five seconds after AFFF is dispensed, all pans will be wand-tested in the sequence contained in the legend. Wand-testing will continue every 5 minutes for a total of 15 minutes.

Figure B-2. Fuel-Securing Test Layout.

F. POSTTEST PROCEDURES

1. Take still photographs of secured fuel and egress test personnel.
2. Drain and wash down all JP-4 and AFFF.
3. Remove cameras and process video immediately.
4. Check instrumentation readings.

SECTION IV

LOCATION AND SITE DESCRIPTION

A. LOCATION

Tyndall AFB is located on the Gulf Coast of Florida, about 10 miles southeast of Panama City, on US Highway 98. The location of the test area for the Tyndall AFB Test Program is within approximately 20 acres of remote, little-used land in the southeast portion of Tyndall Air Force Base, Florida. It is approximately 7 miles from Tyndall main base, 3.6 miles from Mexico Beach (population 800) and 2.4 miles across East Bay from Allanton (population 400) in a 50-square-mile area.

B. SITE GEOLOGY

The soil is characteristic of the coastal lowlands of Western Florida, where fine gray beach sands are underlaid at variable depths by the Atronelle Formation. This material is very permeable and free-draining. The subgrade is a poorly graded sand.

The water table in the area varies with the season and may be anywhere from 4 feet to just below the ground surface, but usually occurs about 2.5 feet below the surface. Surface drainage is normally in a southward direction into a swampy area south and east of the shelter test site. The only surface water in the immediate area is from one large borrow pit resulting from construction, and seasonal surface water in the swampy area southeast of the test site.

SECTION V
SCHEDULE OF EVENTS

ESTIMATED START	ESTIMATED COMPLETION	DESCRIPTION
01 Jul 86	18 Jul 86	Develop test plan, order tests components.
21 Jul 86	30 Aug 86	Prepare test site, install instrumentation.
08 Sep 86	10 Sep 86	Test fuel-securing agents/systems.
15 Sep 86	17 Sep 86	Conduct three personnel egress system tests with smoke.
18 Sep 86	19 Sep 86	Conduct a full-scale personnel egress system test with Halon 1211.
	30 Sep 86	Complete preliminary analysis of test results.
	31 Oct 86	Publish results of tests and develop a generic specification for HAS fuel-securing and personnel egress systems.

SECTION VI

TEST ORGANIZATION

A. OPERATIONS

The field operations organization is shown in Figure B-3. Minor field modifications which affect any aspect of this project will be coordinated and approved by the Test Director.

B. RESPONSIBILITIES

The overall responsibility for the entire test program rests with the Test Director. In addition, he will be responsible for the test event's countdown coordination and procedures, and any extraordinary safety and security precautions during personnel egress test days. The Test Director will delegate his authority when necessary. Specific responsibilities relative to safety, security, communication, instrumentation, photography, and engineering support are contained in the annexes to this appendix.

Test Organization

Project Officer

Mr. Mason

Technical Support - Mr. John Centrone/
Mr. Bill Dees
Ground Safety - Mr. Parsons
Bioenvironmental Engineering
- Lt. Shelton

-----	-----	-----	-----
Instrumentation	Photography	Engineering Support	Security
-----	-----	-----	-----
SMSgt Hollopeter	Mr. Keith Moser	MSgt Lavigne	MSgt Babcock

Figure B-3. Test Organization

ANNEX 1
COUNTDOWN SEQUENCE OF EVENTS

A. PURPOSE

The purpose of this plan is to develop a realistic countdown sequence of events to provide positive control of all activities involved in the dumping of fuel for the securing tests and safe egress of personnel during the egress testings.

B. PROCEDURES AND RESPONSIBILITIES

To eliminate the possibility of injury to personnel and fuel seeping into the ground water system, the schedule of events has been chronologically laid out for all test participants.

FUEL-SECURING TESTS

<u>TIME</u>	<u>OPERATION</u>	<u>OPR TO RESPOND</u>
T - 0:30	Ensure that one fire truck (P-19) is available. See Figure 3 for location.	325 CES/DEF.
T - 0:10	Establish radio contact with all test project personnel to ensure handheld radios are operable.	Test Director
T - 0:05	Conduct complete check of instrumentation and photo equipment.	AFESC Instrumentation
T - 0:02	Ensure that all personnel and equipment are vacated from shelter.	AFESC Test Director
T - 0:00	Spill fuel and apply inerting substance.	NMERI
T + 0:10	Initiate AFFF and fuel evacuation and clean-up.	NMERI/AFESC
T + 0:30	Check shelter to ensure environmental conditions are safe for personnel to enter.	Test Director and Bioenvironmental Engineer
T + 0:40	When "all clear" is given, inspect test site.	All

PERSONNEL EGRESS TESTS

<u>TIME</u>	<u>OPERATION</u>	<u>OPR TO RESPOND</u>
T - 0:30	Ensure one fire truck is on site to provide support. See Fig. 3 for location.	325 CES/DEF.
T - 0:15	Establish radio contact with all test project personnel to ensure hand-held radios are operable.	Test Director
T - 0:10	Place four test subjects at assigned locations in the shelter with four safety personnel. Ensure all are wearing self-contained breathing apparatus and that the safety line is securely fastened.	NMERI
T - 0:05	Complete check of instrumentation and photo equipment.	AFESC Instrumentation
T - 0:02	Ensure that all nonessential personnel and equipment are vacated from shelter.	AFESC Test Director
T - 0:00	Dump smoke or release halon	NMERI
T + 0:10	Evacuate smoke or halon from shelter	NMERI/AFESC
T + 0:20	Inspect test site	All

ANNEX 2
COMMUNICATIONS PLAN

A. PURPOSE

The purpose of this plan is to develop a suitable communications network for the test. The specific objective of this plan is to provide the following:

1. Reliable communications between the test subjects and rescue personnel.
2. Test site communications between fire department and test personnel.
3. Dependable communications with health and safety organizations.

B. PROCEDURES AND RESPONSIBILITIES

1. Two-way radios will be the primary method of communication on the day(s) during fuel spill and total flooding of shelter with either smoke or Halon 1211.

2. Two-way radios will be utilized on the test day to transmit all communications between the test site and all involved agencies. The following areas will be assigned radios:

- Test Director
- Safety
- Fire chief
- NMERI personnel
- Test subjects

3. The events shown will be adhered to during the times indicated. T-hour will represent the local time for the test scheduled which will be determined by the Test Director at least 2 days before the test day. A✓

ANNEX 3 SAFETY PLAN

A. PURPOSE

This safety plan establishes the safety areas for the testing site and all related functions to be conducted at Tyndall Air Force Base, Florida, and identifies the agency responsible for each of these areas. All references to the test throughout this safety plan will pertain to the tests to be conducted at Tyndall Air Force Base, Florida. The detailed safety rules which are applicable to this project are documented herein. Before any fire testing can be conducted at Tyndall Air Force Base, Florida, the Base Fire Chief must be notified. The following safety documents are applicable to this test:

AFOSH Standards
AFR 127-4

B. OVERALL SAFETY RESPONSIBILITY

The HQ AFESC/RDCF Test Director is responsible for enforcing the overall safety program for the test. The Base Fire Chief or his designated representative will act as the safety officer during all actual fire tests and/or tests which involve the use of fire-extinguishing agent. The Test Director is the safety officer for all other events at the test site. The Test Director will maintain close coordination with the Air Defense Weapons Center Ground Safety Officer on all safety matters.

C. SAFETY AREAS

The safety requirements of the test have been divided into three separate and distinct areas to facilitate the establishment of specific requirements for the different areas of operation. The safety requirements are divided into three areas as follows:

1. General Safety
2. Construction Safety
3. Fire Safety

D. GENERAL SAFETY

The responsibility for general site safety resides with AFESC. The authority to execute specific safety directives is delegated to the Test Director. The Public Affairs Office (HQ AFESC/PA) is responsible for notification and publicizing the test (when applicable).

1. Safety Briefing. The Test Director will brief all AFESC personnel and/or supervisors of construction crews on the safety hazards existing within the test site. Supervisors will, in turn, brief their personnel on these hazards.

2. Visitors. Visitors shall not be allowed at the test site without approval of the Test Director or his authorized delegates. Visitors will be instructed on applicable safety regulations.

3. Individual Safety Responsibility. Careful attention to potential hazards involved in work dealing with fire must be stressed at all levels of responsibility. The purpose of the safety rules outlined herein is to present the most important elements in setting controlled fires. These rules do not cover all the possible hazards or safety precautions necessary at the site. As new problems arise, new safety measures will be established to cope with them. In the interim, common sense must be applied to ensure that safety prevails. This entire Safety Plan must be closely followed by all personnel and enforced by all supervisors. The procedures contained herein shall be accepted as minimum standards until such time as the Test Director, with the concurrence of the AFESC Safety Officer, authorizes deviation therefrom.

4. Vehicles. Speeds shall not exceed 20 mi/h when driving on unpaved roads. Seat belts will be used at all times while vehicles are in motion. When a vehicle is parked, the hand brake will be set and the transmission put in park (automatic transmissions) or reverse (manual transmissions).

5. Accident Reporting (Emergency).

(a) Scope. This standard procedure is intended as a guide to ensure expedient handling and care of personnel injured in an accident or disaster. All "postemergency" reporting and investigation of an accident

will be performed in accordance with applicable Air Force regulation not considered to be within the scope of this standard procedure.

(b) Responsibility. Every person involved in this program must be completely familiar with the emergency reporting procedures established by this plan, and must implement these procedures immediately in the event of an accident. The Test Director must familiarize all supervisors with standard procedure. The supervisor must familiarize subordinate personnel with the procedures established by this plan.

(c) Emergency Reporting Procedures. In the event of an accident at the test site, the following procedures shall be followed:

(1) The senior supervisor at the scene of an accident shall direct appropriate first aid. Caution shall be exercised to prevent aggravation of an accident-related injury.

(2) Tyndall AFB Hospital Ambulance Service shall be notified immediately by calling Extension 2333. The nature of the accident, including the apparent condition of injured personnel and the location of the test site, shall be reported to the medical personnel. The Test Director or, in his absence, the Senior Supervisor, shall determine whether to attempt to transfer the injured to a hospital or to request emergency ambulance support.

(3) The Test Director or, in his absence, the Senior Supervisor, shall determine the seriousness of the accident. If the accident is not serious enough to require emergency hospitalization or ambulance service, the injured person shall be taken to a doctor or hospital by normal means of transportation.

6. First Aid. An adequate supply of first-aid items shall be maintained at the site. These items shall be properly stored and periodically inspected to ensure their effectiveness in case of an emergency.

7. Fire Prevention Reporting and and Emergency Procedures. This paragraph defines the responsibility for fire prevention and reporting procedures related to the test.

a. Responsibility. The Test Director shall be responsible for implementation of the procedures established by this plan. All onsite personnel must be completely familiar with these procedures to ensure proper response to an emergency.

b. Fire Prevention Procedures. The procedures listed below shall be followed in an effort to reduce chances of an uncontrolled fire.

(1) One base fire crash rescue vehicle shall be pre-positioned at the test site.

(2) The Test Director shall instruct all personnel on the procedures to follow in case of fire, and the location and use of available fire extinguishers.

(3) All engines shall be shut down with ignition off, before and during any fueling. Care shall be exercised to ensure that the equipment is not hot enough to ignite the fuel if it should be spilled during the refueling operation. Rubbish, waste, and industrial residue shall be placed in metal drums, and removed from the site when drums are full, or before.

(4) Good housekeeping is essential to fire prevention. Oiled-soaked, greasy, and paint-soaked rags will be deposited in the same cans. All cans will be equipped with tight-fitting or self-closing lids.

8. Filling Halon Containers. The procedures that shall be followed in handling and charging test halon cylinders are:

a. Two personnel will be present during all halon transfer operations.

b. The transfer process may occur at Base Fire Station Number One or at the test site.

c. The halon supply cylinders may be moved to Fire Station One when required. The empty Government-owned cylinders will be returned to Base Supply.

d. Movement of the filled cylinders will be conducted in accordance with established safety procedures and regulations.

ANNEX 4
ENGINEERING SUPPORT PLAN

A. PURPOSE

This plan defines procedures and responsibilities for providing engineering support for this test program.

B. PROCEDURES

The descriptions of the test specimens, test preparations, and post-test procedures are contained in Section III. The Engineering Support Section will be involved directly or indirectly in most of this effort.

C. RESPONSIBILITIES

The Engineering Support Section, in conjunction with construction personnel, will:

1. Inspect and verify the operation of the fuel drainage system for Hardened Aircraft Shelter (HAS).
2. Provide fuel movement and transfer system.
3. Construct curbing across front and rear door openings of HAS.
4. Verify installation of the instrumentation cable duct from test site to third-generation shelter.
5. Provide electrical support for installation of strobe and high-intensity lighting to mark personnel exit in HAS.
6. Provide equipment support, as necessary.
7. Collect test data: temperature; gas concentration.
8. Perform miscellaneous tasks as needs arise.

ANNEX 5

INSTRUMENTATION PLAN

A. PURPOSE

This plan describes the procedures and responsibilities for instrumentation and data collection of this test program.

B. PROCEDURES

For each of the tests, temperature and gas concentration will be collected in the HAS structure. The instrumentation layout and gas sampling locations are the same as those utilized during previous HAS testing.

C. RESPONSIBILITIES

1. The instrumentation section is responsible for the entire data acquisition process, including:

- a. Recording
- b. Timing of personnel escape efforts
- c. Quality assessment
- d. Initial plotting
- e. Corrections
- f. Analysis of results

2. AFESC will:

a. Install the gages and cable which will be provided by the New Mexico Engineering Research Institute (NMERI).

b. Provide personnel support for system setup and operation.

ANNEX 6
PHOTOGRAPHIC SUPPORT PLAN

A. PURPOSE

Both still photographs and videotape recordings are needed to provide documentary records of the test. Such records include coverage of the undisturbed site, construction and progress, and other areas of general interest. Also required is technical data photography showing results of the test events. This plan provides procedures and responsibilities for the photographic support needed for the HAS fuel securing and personnel egress systems.

B. PROCEDURES

1. Videocassette recorder (VCR) cameras will be located in the south-east corner of the HAS. They will be placed on tripods in the center of the HAS with one pointing at the personnel exit and one at ceiling strobe lighting system. All camera locations for each of the events shall be documented in the results of each test series.

2. Cameras in the test structure will record the generated environment. Protection for these cameras will be the responsibility of NMERI. The cameras will be installed so that they may be remotely operated from outside the test shelter.

3. The Test Director will edit all film coverage. All film and prints must be labeled. Date, time, location, and event number or subject title must be included in at least one view of each scene or item. Photographic records of site operations and construction will be maintained by the Test Director.

C. RESPONSIBILITIES

1. AFESC will furnish and install (as required):
 - a. Platforms for photographic equipment
 - b. Power for cameras and lighting
 - c. Power cable
2. NMERI will provide:
 - a. VCR cameras, film, timing generators, control cable, and any lighting required in addition to installed shelter lighting.
 - b. Switch closure (relays) with desired timing for cameras' start.
 - c. Photographers to set up and take down cameras and care for cameras and film.
 - d. Technical still photography before and after each test.
 - e. Processing, printing, and initial editing of film.
 - f. System check-out and operation before each test series.

APPENDIX C
HALON 1211 CONCENTRATIONS VERSUS TIME CURVES

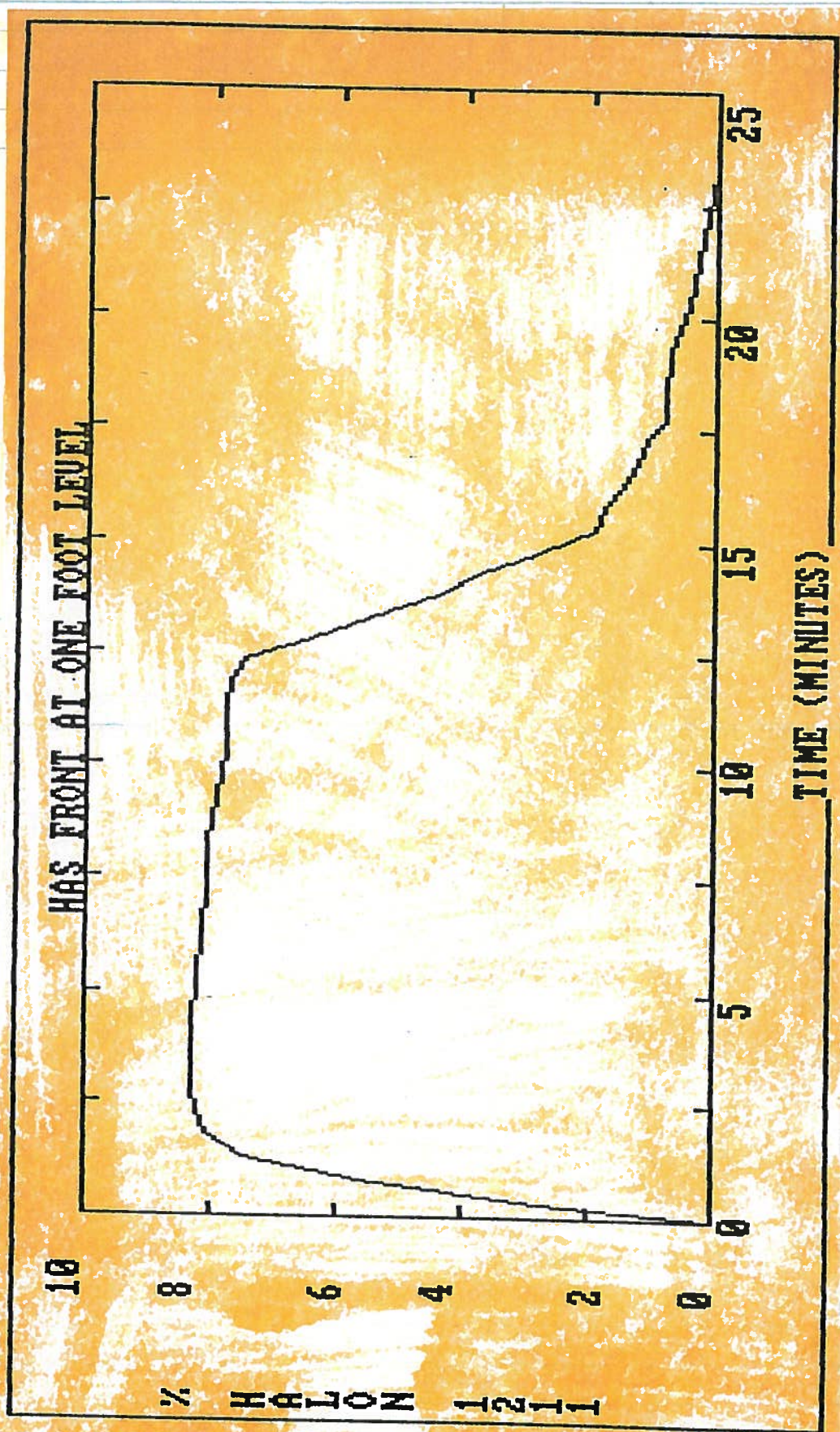


Figure C-1. Halon Concentration versus Time Curve, HAS Front, 1-Foot Level.

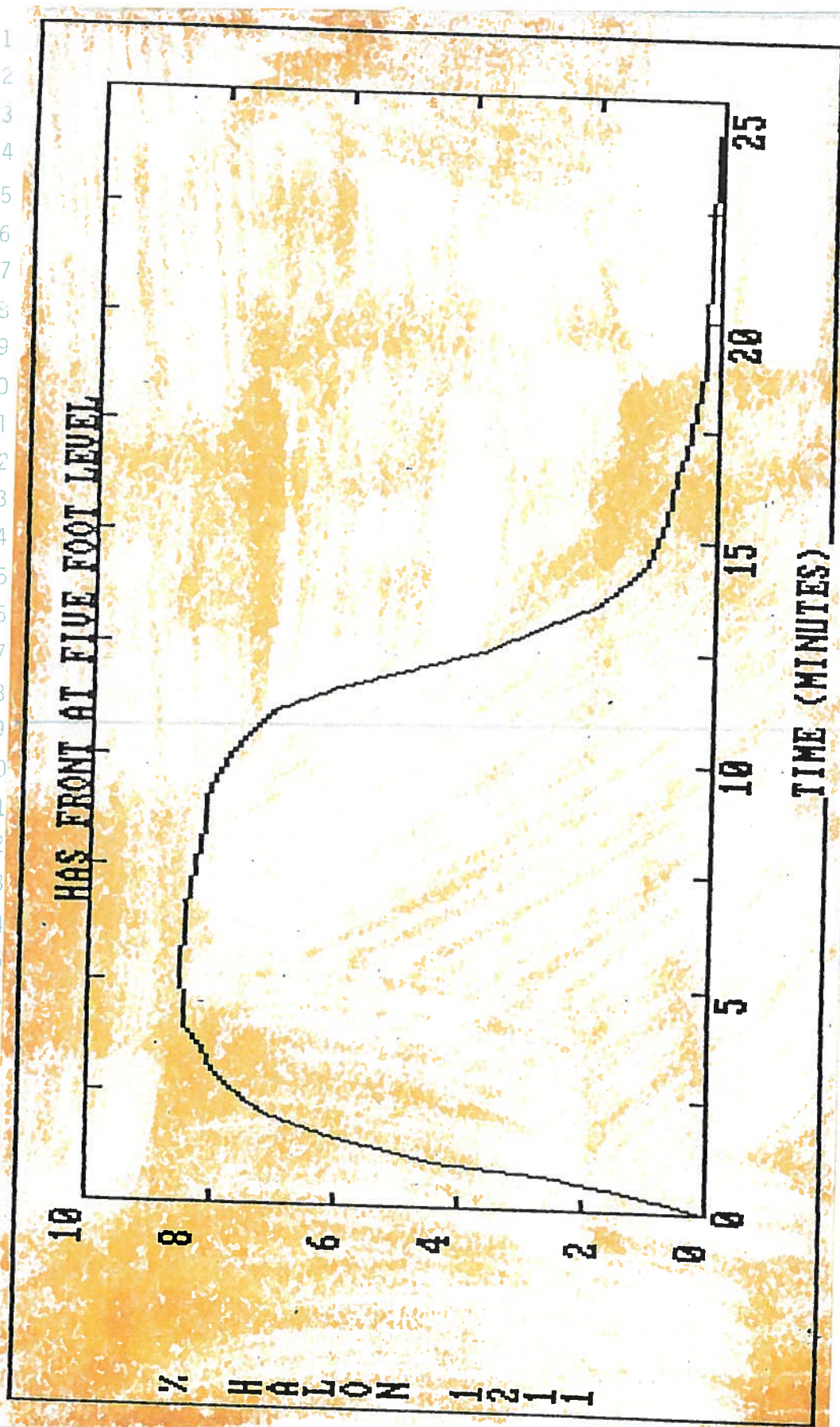


Figure C-2. Halon Concentration versus Time Curve, HAS Front, 5-Foot Level.

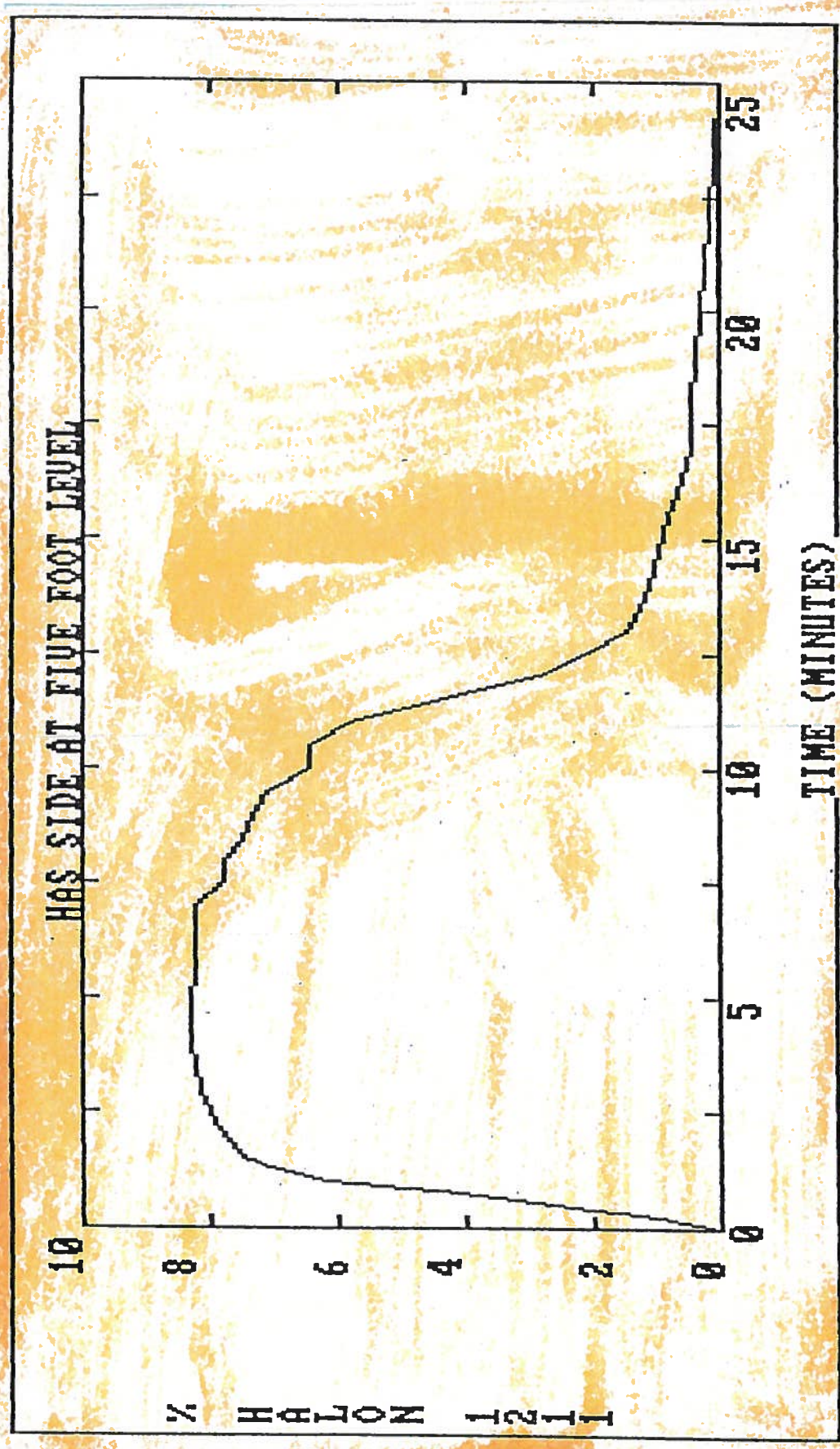


Figure C-3. Halon Concentration versus Time Curve, HAS Side, 5-Foot Level.

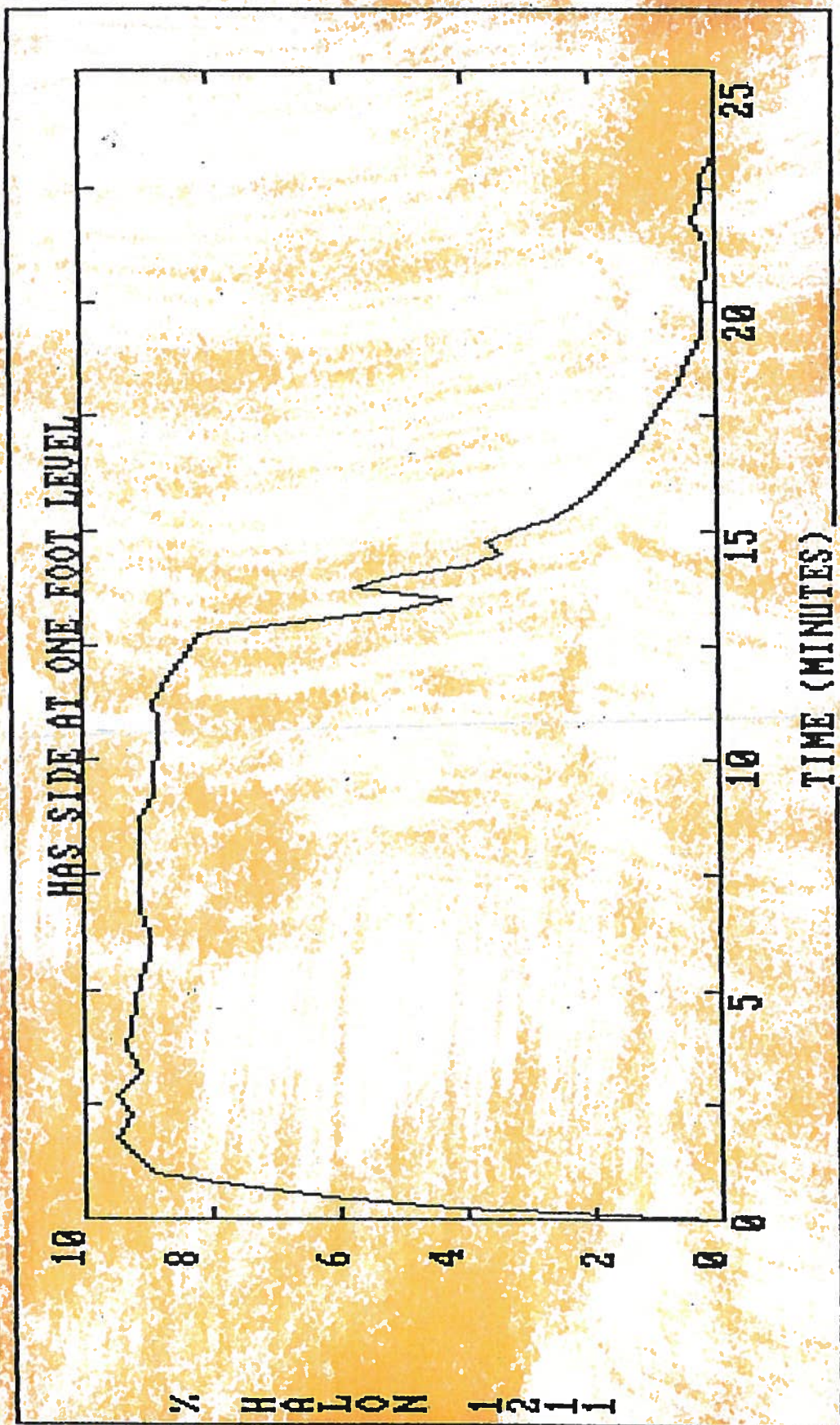


Figure C-4. Halon Concentration versus Time Curve, HAS Side, 1-Foot Level.



Figure C-5. Halon Concentration versus Time Curve, HAS Rear, 1-Foot Level.

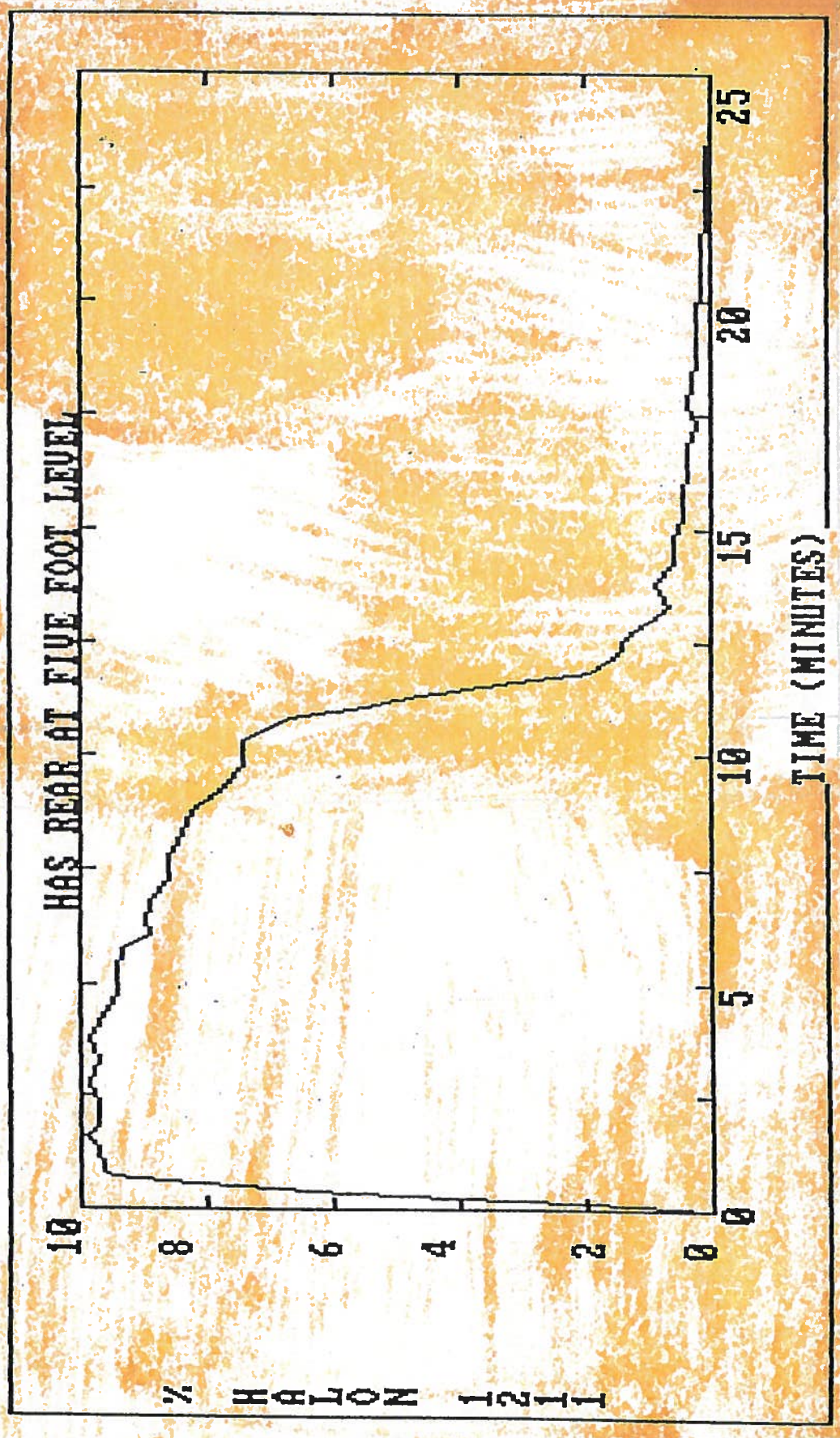


Figure C-6. Halon Concentration versus Time Curve, HAS Rear, 5-Foot Level.

APPENDIX D
TEMPERATURE PROFILES FOR HAS HALON 1211 DISCHARGE

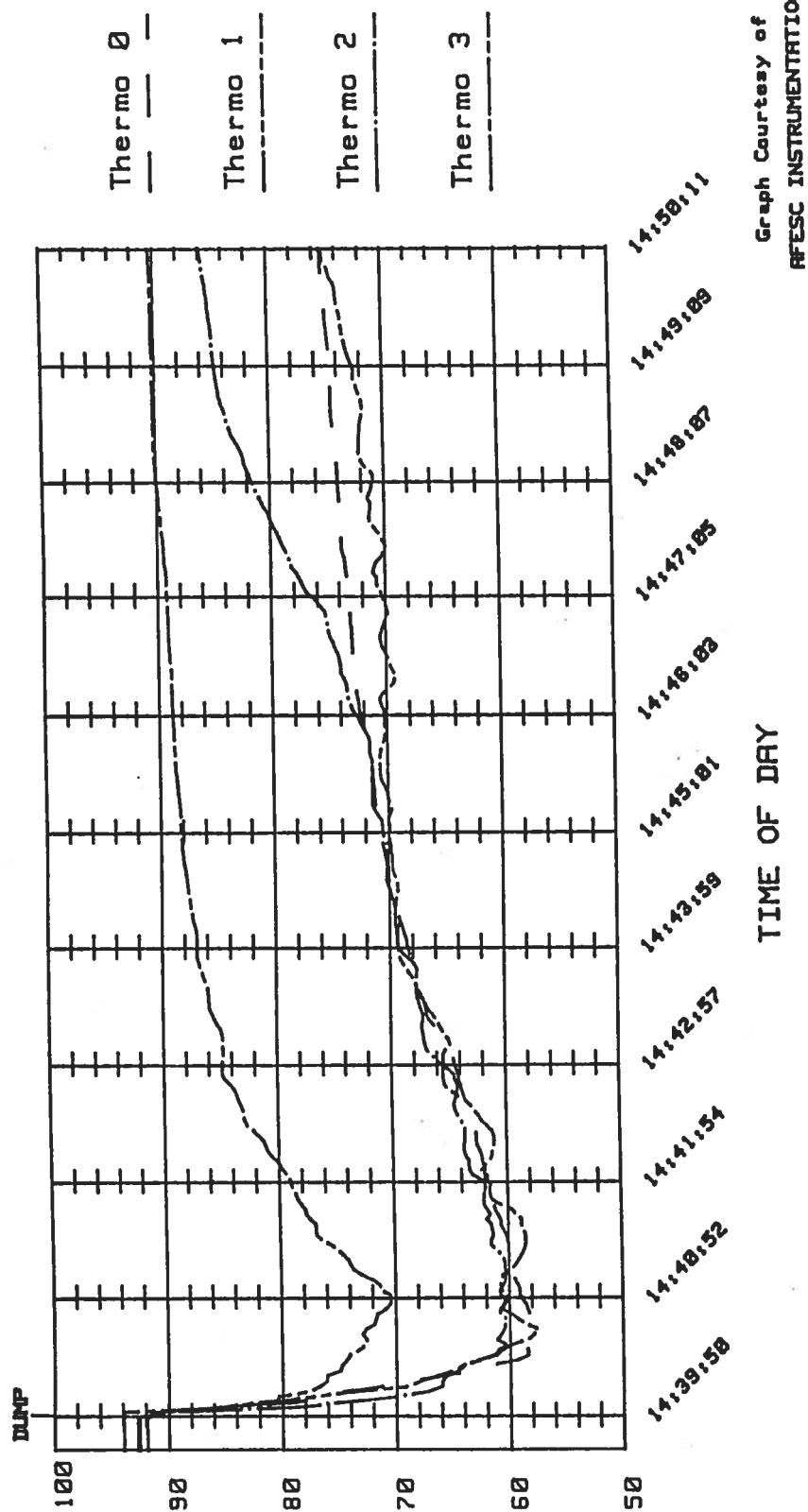


Figure D-1. Temperature Profiles for Halon 1211 Discharge, Thermocouples 0-3.

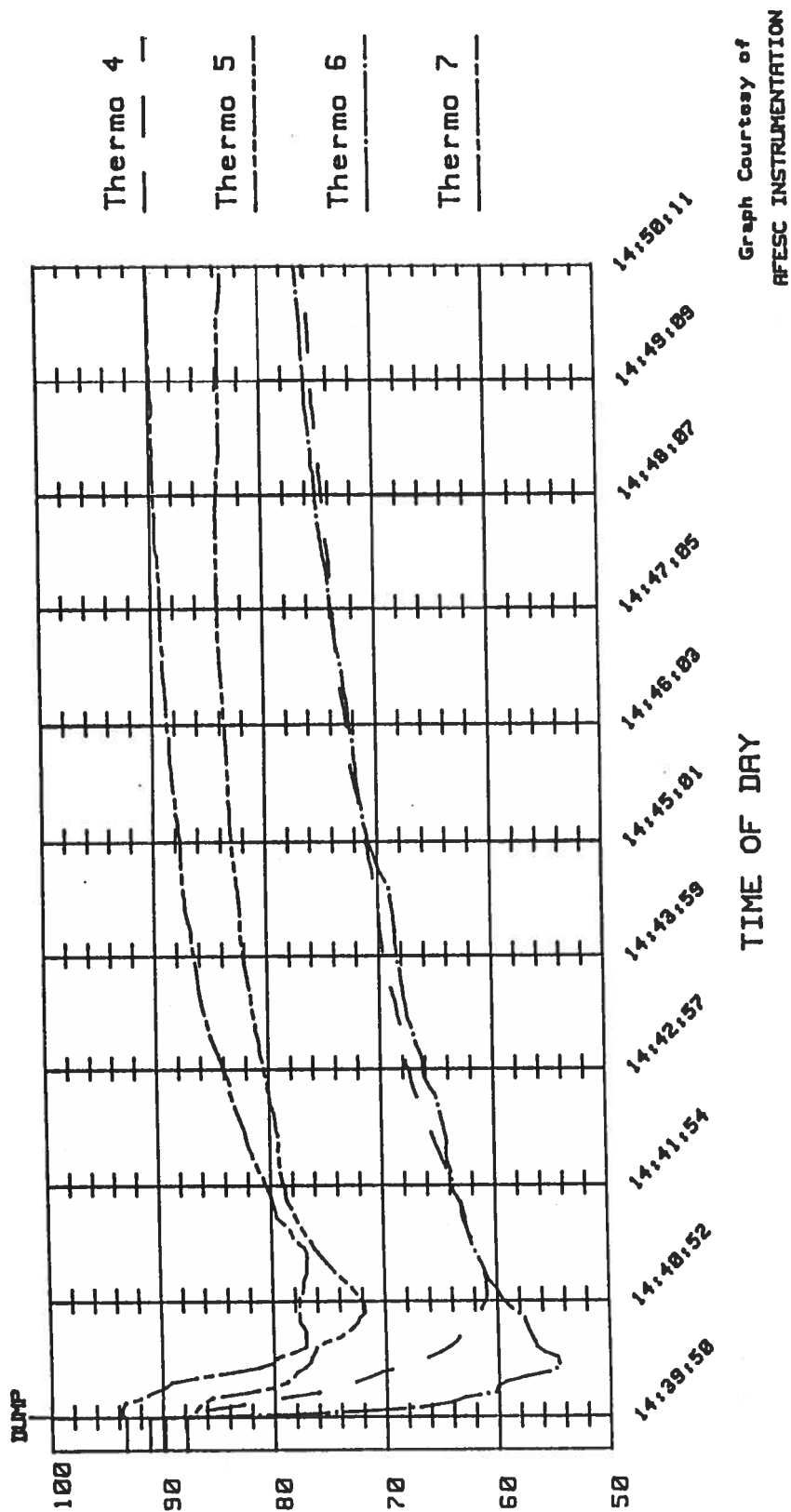


Figure D-2. Temperature Profiles for Halon 1211 Discharge, Thermocouples 4-7.

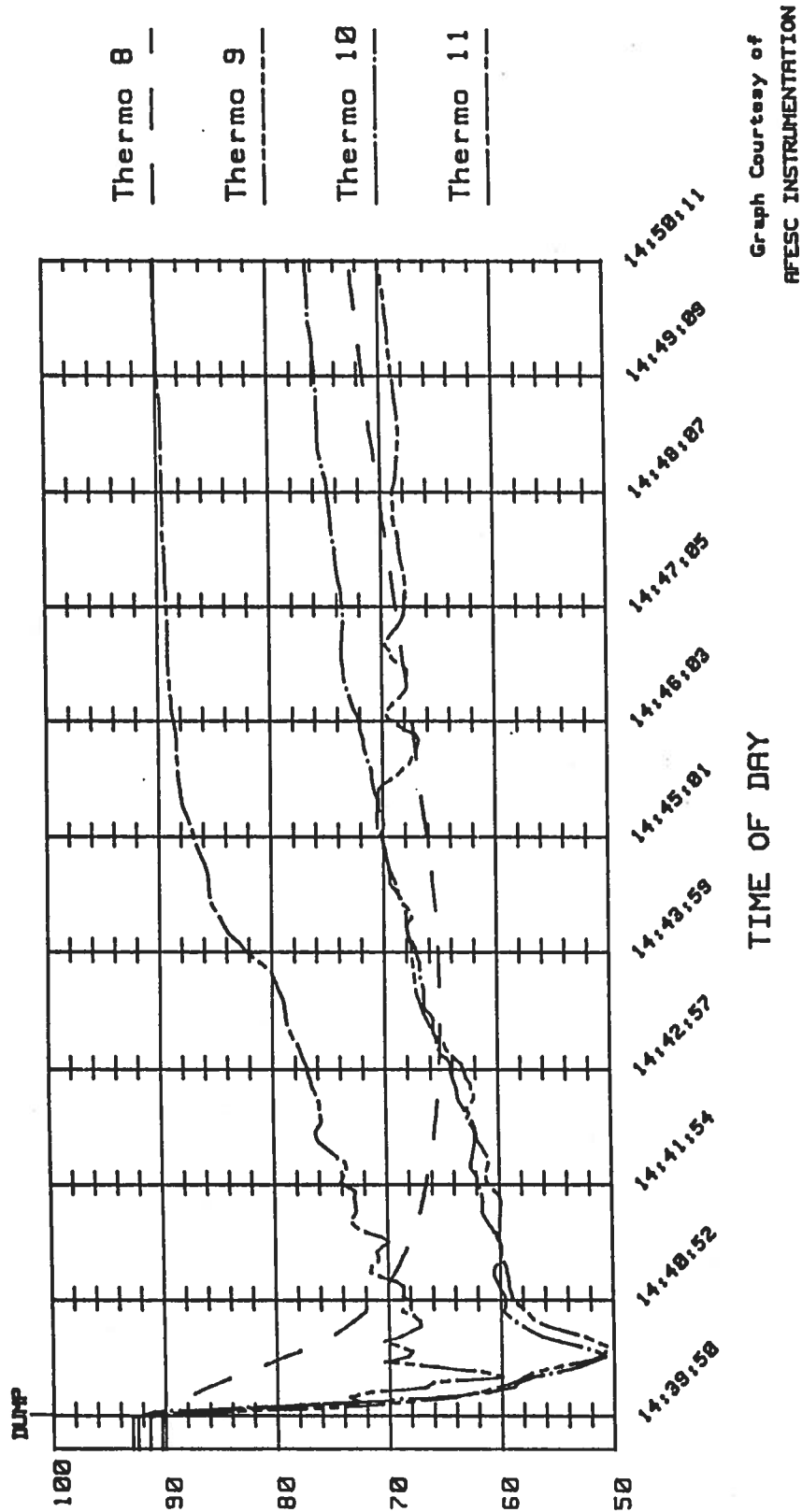


Figure D-3. Temperature Profiles for Halon 1211 Discharge, Thermocouples 8-11.

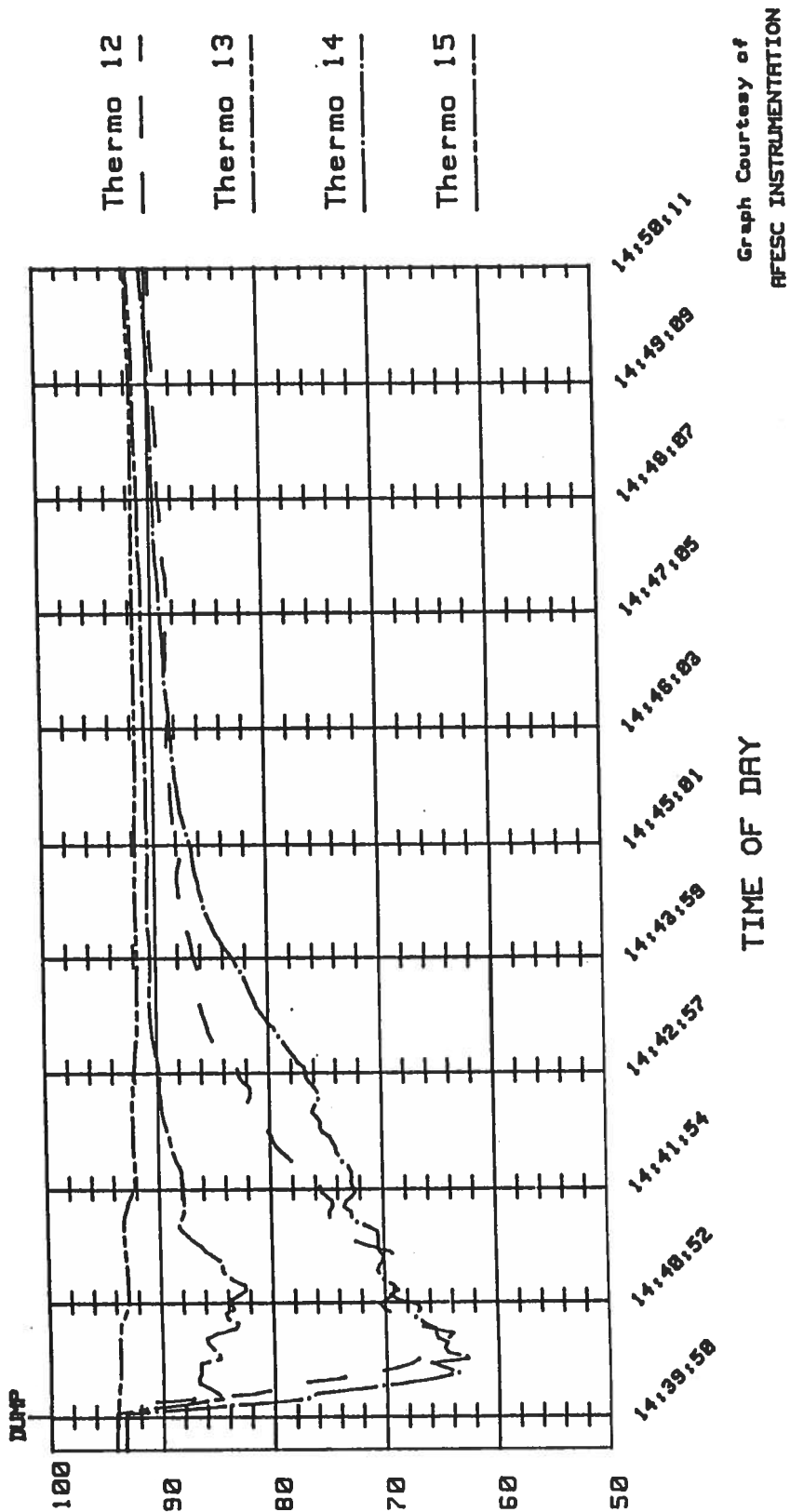


Figure D-4. Temperature Profiles for Halon 1211 Discharge, Thermocouples 12-15.

TABLE D-1. THERMOCOUPLE LOCATIONS FOR THE HAS HALON 1211 DISCHARGE.

Thermocouple	Location	Height, feet
0	Front	1
1	Front	5
2	Front	10
3	Front	15
4	Side	1
5	Side	5
6	Side	10
7	Side	15
8	Rear	1
9	Rear	5
10	Rear	10
11	Rear	15
12	Approximately 7 feet from side wall and 37 feet from rear of HAS	14
13	Approximately 10 feet from side wall and 37 feet from rear of HAS	20
14	Approximately 30 feet from side wall and 37 feet from rear of HAS	15
15	Approximately 30 feet from side wall and 37 feet from rear of HAS	18

APPENDIX E
PURCHASE DESCRIPTION,
PERSONNEL EGRESS SYSTEM FOR
HARDENED AIRCRAFT SHELTERS (HAS)

1.0 SCOPE

1.1 General

1.1.1 This purchase description covers the details of a personnel egress system and the components needed for installation in HAS.

1.2 System Requirements

1.2.1 System Requirements are the following:

- 1.2.1.1 Directional audio device.
- 1.2.1.2 Directional high-intensity light.
- 1.2.1.3 Floor-fixed directional arrows--reflective or phosphorescent.
- 1.2.1.4 Five-minute breathing device.
- 1.2.1.5 Manual personnel accounting device.

1.3 Design Requirements

1.3.1 System design requirements are the following:

- 1.3.1.1 System and Components to be designed for a temperature environment of -20 to +150 °F.
- 1.3.1.2 System and Components to be designed for use in all standard Hardened Aircraft Shelters.
- 1.3.1.3 System and Components to be designed for economical installation and maintenance.

1.3.1.4 System and Components to be designed so as to not create a safety hazard within the HAS.

1.3.1.5 System and Components to be designed to all applicable National fire Protection Association (NFPA) standards.

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents

2.1.1 Specifications and Standards

The following documents are intended to form a part of the specification. Unless otherwise specified, the version in effect on the date of invitation for bids or request for proposal shall apply.

Military Specifications:

MIL-S-901

Military Standards:

MIL-STD-210	Climate Extremes for Military Equipment
MIL-STD-781	Reliability Testing for Engineering Development Qualification and Production
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-810	Environmental Test Methods
MIL-STD-1472	Human Engineering Design Criteria for Military System, Equipment and Facilities
MIL-STD-1516	Unified Code for Coatings and Finishes for DOD Material

(Copies of Military Specifications and Standards required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3.0 REQUIREMENTS

3.1 Preproduction Article(s)

The supplier will furnish, within the time period specified, one Personnel Egress System for Hardened Aircraft Shelters to demonstrate, before starting production, that production methods and choice of design criteria will produce an egress system which complies with the requirements of this purchase description. Examination and testing of components and system shall be those specified herein. Any changes or directions subsequent to the tested preproduction system shall be subject to the approval of the contracting officer. Approval of the preproduction system by the contracting agency shall not relieve the supplier of the contractual obligation to furnish extinguishing systems conforming to the details of this purchase description or the accepted standard of quality provided in the first article test.

3.2 Personnel Egress System For Hardened Aircraft Shelters

3.2.1 Egress Identification System

The Egress Identification System will provide a combination of complementing directional stimuli which, acting together, will enable personnel trapped in the HAS during a halon discharge to egress the HAS in a safe, controlled manner and in less than 3 minutes. The system shall:

3.2.1.1 Be complementary and designed for installation in the HAS.

3.2.1.2 Be easily used by semitrained personnel.

3.2.1.3 Be designed to achieve safe, controlled egress in less than 3 minutes.

3.2.1.4 Be economical to install and essentially maintenance free.

3.2.1.5 Not interfere with normal HAS operations.

3.2.2 Personnel Breathing System

The Personnel Breathing System is to permit personnel trapped in a HAS where a complete or partial Halon 1211 discharge has taken place to have a safe, reliable, and immediately accessible 5-minute source of purified breathing air available. The system shall meet MSHA/NIOSH requirements for closed-circuit self rescuers and shall:

3.2.2.1 Be designed for wear at all times within the HAS.

3.2.2.2 Be easily used by semitrained personnel.

3.2.2.3 Provide at least 5 minutes of pure breathing air to the user in a manner not hazardous to the user's health nor infringing on his/her ability to egress the Halon 1211-obscured HAS.

3.2.2.4 Be economical and maintenance-free.

3.2.2.5 Be allowed to be worn at a noninterfering location on the wearer's person and readily accessible for immediate donning.

3.2.2.6 Include the provision of eye protection.

3.2.3 Personnel Accounting System

The Personnel Accounting System shall provide a manual and/or auditory means of accounting for all personnel within the HAS at any time.

3.2.3.1 The manual system shall:

3.2.3.1.1 Be readily visible and accessible at a location outside the HAS to all personnel entering and egressing the HAS.

3.2.3.1.2 Be immediately visible to a fire/rescue crew approaching the HAS at any time of the day and under any weather conditions.

3.2.3.1.3 Be economical to install and essentially maintenance-free.

3.2.3.1.4 Be located where it does not interfere with normal HAS operations.

3.2.3.2 The audio system shall:

3.2.3.2.1 Comply with the requirements of NFPA Standard 1982.

3.2.3.2.2 Be equipped with a rotary OFF/ON Auto Switch requiring two distinct actions to change functions. All function positions shall be clearly marked for ease of reading by the wearer and shall be so designed that they can be operated by a person wearing gloves.

3.2.3.2.3 Utilize two motion detectors.

3.2.3.2.4 Be so constructed that, when in the activated position, the alarm will begin to sound when motion has stopped for more than 25 seconds.

3.2.3.2.5 Include a manual switch position to activate the alarm if necessary.

3.2.3.2.6 Emit an audible "beep" signal within 1 second to indicate when the system has been put in the automatic position; in addition, there should be a visual indicator easily seen in the dark. Also there shall be a low tone warning signal sound that will precede the urgent sound system. This volume signal shall be between 30 percent and 50 percent of the DBA of the alarm system, and shall continue for 7 ± 3 seconds.

3.2.3.2.7 Have an audio output level of a minimum 95 DBA, measured at a distance of 3 m (9.9 ft). Signal frequency shall be no less than 1,000 Hz or more than 4,000 Hz. Audio tone shall be directional in character.

3.2.3.2.8 Provide for two low-battery warning signals to indicate when the battery condition will not support the 95 DBA sound for a period of 1 hour. One signal shall be auditory, and the other shall be visual.

3.2.3.2.9 Weigh no more than 13 ounces with battery(s) installed.

3.3. Design and Manufacturing

The egress system shall be designed and manufactured to permit ease of installation, inspection, repair, maintenance and storage. All components of the egress system will be designed to permit easy and economical installation.

3.4 Materials and Construction

Materials of construction of the system and components shall be selected on the basis of weight, cold and heat temperature directly, functional service, corrosion-resistance, environmental factors, and service factors. All alloy parts shall be provided with corrosion-resistant plating protection in accordance with MIL-STD-1516. Where plating protection is not practicable, protective coating of paint will be specified.

3.5 Human Engineering

Human engineering design criteria and principles shall be applied in accordance with MIL-STD-1472 to achieve effective integration of personnel into the design of the system. The human engineering effort shall be provided to develop or improve the system interface during operation, installation, and maintenance to make effective, economical demand upon personnel resources, skills, training, and cost.

3.6 Durability

The personnel egress system shall perform as required after exposure to the following environmental tests.

3.6.1 High Temperature
According to method 501.2, MIL-STD-810

3.6.2 Temperature Shock
According to method 503.2, MIL-STD-810

3.6.3 Humidity
According to method 507.2, MIL-STD-810

3.6.4 Leakage
According to method 512.2, MIL-STD-810

3.6.5 Vibration
According to method 514.3, MIL-STD-810

3.7 Identification and Marking

The contractor shall provide identification and marking of all items of the securing device in accordance with MIL-STD-130.

3.8 Workmanship

The device shall be manufactured in accordance with the specifications and standards contained in this document and in compliance with accepted commercial practices.

3.9 Acceptance Test

Each prototype or batch egress system built shall be subject to an operational acceptance test. The procedure for this test shall be prepared by the contractor and approved by the contracting officer prior to delivery of production units.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein, except as otherwise specified. The supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specifications where such inspections are deemed requirements.

4.2 Classification of Inspection

Preparation Inspection (see paragraph 4.3)

Acceptance Inspection (see paragraph 4.6)

4.3 Preproduction Inspection

One test article of the egress system shall be examined and tested as specified in paragraphs 3.6 and 3.7. Presence of one or more defects shall be cause for rejection.

4.4 Lot

For inspection purposes, a lot shall consist of all egress systems submitted for inspection at the same time and place.

4.5 Sampling

One egress system shall be subjected to test specified in paragraph 4.7.

4.6 Acceptance Inspection

Each egress system shall be examined as specified in paragraphs 4.6.1 and 4.6.2. Presence of one or more defects shall be cause for rejection.

4.6.1 Examination

Each egress system shall be examined for the following or similar defects including:

- Missing Parts

- Nonconformance to approved drawings

- Nonspecified materials of construction

- Damaged components or parts

- Noncompliance with purchase description

- Void area of primer, paint, or plating

4.6.2 Operation

Each egress system shall be checked to assure proper assembly and performance.

4.7 Preproduction Tests

One egress system shall be tested at the Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, and shall demonstrate:

- 4.7.1 Capability to be operable at any time.

- 4.7.2 Capability to mechanically turn on and shut off electrical components of the system.

- 4.7.3 Capability of the egress system to enable egress under Halon 1211 conditions.

- 4.7.4 Simplicity of maintenance while installed.

- 4.7.5 Simplicity of maintenance and storage when not installed.

5.0 PREPARATION FOR DELIVERY

5.1 Packaging and Packing

Each egress system shall be packaged in individual containers to afford adequate protection against damage during shipment from the supplier to the destination (see paragraph 6.2). Containers and packing shall comply with uniform freight classification for National Motor Freight Classification.

5.2 Marking

In addition to any other marking required by the order of contract (see paragraph 6.2), the interior package and exterior shipping container shall be marked in accordance with MIL-STD-129, as applicable.

6.0 NOTES

6.1 Intended Use

The egress system will be located/installed in the Hardened Aircraft Shelter, at locations determined appropriate by the manufacturer to provide optimum egress effectiveness.

6.2 Contract Data Requirements

Any data item to be delivered under contract for items should be specifically called for in the contract in accordance with the applicable regulation of the procuring activity (Form DD 1423).

APPENDIX F
PURCHASE DESCRIPTION,
FUEL-SECURING SYSTEM FOR
HARDENED AIRCRAFT SHELTERS (HAS)

1.0 SCOPE

1.1 General

1.1.1 This purchase description covers the details of a fuel-securing system and the components needed for installation in Hardened Aircraft Shelters.

1.2 System Requirements

1.2.1 System Requirements are the following:

- 1.2.1.1 Self-contained agent system.
- 1.2.1.2 Capable of dispensing agent effectively.
- 1.2.1.3 Mountable on a secure wall.
- 1.2.1.4 Capable of being operated by semitrained personnel.
- 1.2.1.5 Rechargeable agent system.

1.3 Design Requirements

1.3.1 System design requirements are the following:

- 1.3.1.1 System and Components to be designed for a temperature environment of -20 to 150 °F.
- 1.3.1.2 System and Components to be designed for use in all standard Hardened Aircraft Shelters.
- 1.3.1.3 System and Components to be designed for economical installation and maintenance.

1.3.1.4 System and Components to be designed so as to not create a safety hazard within the HAS.

1.3.1.5 System and Components to be designed to all National Fire Protection Association (NFPA) standards for wet chemical agents used to extinguish liquid fuel fires and to secure unburned fuel vapors from ignition.

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents

2.1.1 Specifications and Standards

The following documents are intended to form a part of the specification. Unless otherwise specified, the version in effect on the date of invitation for bids or request for proposal shall apply.

Military Specifications:

MIL-S-901

Military Standards:

MIL-STD-210 Climate Extremes for Military Equipment

MIL-STD-781 Reliability Testing for Engineering
Development Qualification and Production

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-130 Identification Marking of U.S. Military Property

MIL-STD-810 Environmental Test Methods

MIL-STD-1472 Human Engineering Design Criteria for Military
Systems, Equipment and Facilities

MIL-STD-1516 Unified Code for Coatings and Finishes for DOD
Material

(Copies of Military Specifications and Standards required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3.0 REQUIREMENTS

3.1 Preproduction Article(s)

The supplier will furnish, within the time period specified, five Fuel-Securing Systems for Hardened Aircraft Shelters to demonstrate, before starting production, that production methods and choice of design criteria will produce an extinguishing system which complies with the requirements of this purchase description. Examination and testing of components and system shall be those specified herein. Any changes or directions subsequent to the tested preproduction model shall be subject to the approval of the contracting officer. Approval of the preproduction model by the contracting agency shall not relieve the supplier of the contractual obligation to furnish extinguishing systems conforming to the details of this purchase description or the accepted standard of quality provided in the first article test.

3.2 Fuel-Securing System For Hardened Aircraft Shelters

3.2.1 Extinguishing Device

The fire extinguishing device is to prevent ignition of liquid fuel and its vapors and provide burnback resistance to small fires in Hardened Aircraft Shelters (HAS). The device shall be:

- 3.2.1.1 Self-contained and designed for installation in the HAS.
- 3.2.1.2 Easily used by semitrained personnel.
- 3.2.1.3 Designed to easily blanket the shelter with chemical compound to extinguish the fire and prevent reignition for at least 10 minutes.
- 3.2.1.4 Rechargeable.

3.2.1.5 Easily and economically installed on a secure wall.

3.2.1.6 Designed so that the agent will not be released unless by the operator of the equipment.

3.3. Design and Manufacturing

The extinguishing system shall be designed and manufactured to permit ease of installation, inspection, repair, maintenance, and storage. All components of the extinguishing system will be designed to permit easy and economical installation.

3.4 Materials and Construction

Materials and construction of the system and components will be selected on the basis of weight, tolerance to cold and hot temperatures directly, functional service, corrosion resistance, environmental factors, extinguishing agent capability, and service factors. All alloy parts shall be provided with corrosion-resistant plating protection in accordance with MIL-STD-1516. Where plating protection is not practicable, protective coating of paint will be specified.

3.5 Human Engineering

Human engineering design criteria and principles shall be applied in accordance with MIL-STD-1472 to achieve effective integration of personnel into the design of the system. The human engineering effort shall be provided to develop or improve the system interface during operation, installation and maintenance to make effective, economical demand upon personnel resources, skills, training, and cost.

3.6 Durability

The extinguishing device shall perform as required after exposure to the following environmental tests.

- 3.6.1 High Temperature
According to method 501.2, MIL-STD-810
- 3.6.2 Temperature Shock
According to method 503.2, MIL-STD-810
- 3.6.3 Humidity
According to method 507.2, MIL-STD-810
- 3.6.4 Leakage
According to method 512.2, MIL-STD-810
- 3.6.5 Vibration
According to method 514.3, MIL-STD-810
- 3.7 Identification and Marking

The contractor shall provide identification and marking of all items of the securing device in accordance with MIL-STD-130.

3.8 Workmanship

The device shall be manufactured in accordance with the specifications and standards contained in this document and in compliance with accepted commercial practices.

3.9 Acceptance Test

Each prototype or batch extinguishing device built shall be subject to an operational acceptance test. The procedure for this test shall be prepared by the contractor and approved by the contracting officer prior to delivery of production units.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the government. The Government reserves the right to perform any of the inspections set forth in the specifications where such inspections are deemed requirements.

4.2 Classification of Inspection

Preparation Inspection (see paragraph 4.3)

Acceptance Inspection (see paragraph 4.6)

4.3 Preproduction Inspection

Five test articles of the extinguishing device shall be examined and tested as specified in paragraphs 3.6 and 3.7. Presence of one or more defects shall be cause for rejection.

4.4 Lot

For inspection purposes, a lot shall consist of all extinguishing devices submitted for inspection at the same time and place.

4.5 Sampling

Five extinguisher units shall be subjected to test specified in paragraph 4.7.

4.6 Acceptance Inspection

Each extinguishing device shall be examined as specified in paragraphs 4.6.1 and 4.6.2. Presence of one or more defects shall be cause for rejection.

4.6.1 Examination

Each extinguishing device shall be examined for the following or similar defects including:

- Missing parts
- Nonconformance to approved drawings
- Nonspecified materials of construction
- Damaged components or parts
- Noncompliance with purchase description
- Void area of primer, paint or plating

4.6.2 Operation

Each extinguishing device shall be checked to assure proper assembly and performance.

4.7 Preproduction Tests

Five extinguishing devices shall be tested at the Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, and shall demonstrate:

4.7.1 Capability to be operable at any time.

4.7.2 Capability to mechanically turn on and shut off extinguishing system.

4.7.3 Capability of the extinguishing agent to prevent flashback or restarting of the fire after initial extinguishment for at least 10 minutes.

4.7.4 Simplicity of maintenance while installed.

4.7.5 Simplicity of maintenance and storage when not installed.

4.7. 6 Capability of extinguishing device to perform operationally and to extinguish small fuel fires as specified above after completion of the environmental tests (see paragraph 3.6).

5.0 PREPARATION FOR DELIVERY

5.1 Packaging and Packing

Each extinguishing device will be packaged in individual containers to afford adequate protection against damage during shipment from the supplier to the destination (see paragraph 6.2). Containers and packing shall comply with uniform freight classification for National Motor Freight Classification.

5.2 Marking

In addition to any other marking required by the order of contract (see paragraph 6.2), the interior package and exterior shipping container shall be marked in accordance with MIL-STD-129, as applicable.

6.0 NOTES

6.1 Intended Use

The self-contained extinguishing device will be located/installed in the HAS, on the rear wall, on a firm base adequate to support the heavy weights anticipated. The self-contained extinguisher shall have the intended use of securing spilled fuel in a HAS, extinguishing small fires and preventing burnback of exposed fuel surfaces.

6.2 Contract Data Requirements

Any data item to be delivered under contract for items should be specifically called for in the contract in accordance with the applicable regulation of the procuring activity (Form DD 1423).